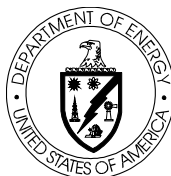


May 1999

# *Field Operations Program Activities Status Report*

*Fiscal Years 1997 through mid-1999*



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Fiscal Years 1997 through mid-1999

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## EXECUTIVE SUMMARY

The Field Operations Program is an electric vehicle testing and evaluation program sponsored by U.S. Department of Energy and managed by the Idaho National Engineering and Environmental Laboratory. The Program's goals are to

- Evaluate electric vehicles in real-world applications and environments
- Support electric vehicle technology advancement
- Develop infrastructure elements necessary to support significant electric vehicle use
- Support increased use of electric vehicles in federal fleets
- Increase overall awareness and acceptance of electric vehicles.

This report covers Program activities from fiscal year 1997 through mid-fiscal year 1999. The Field Operations Program succeeded the Site Operator Program, which ended in September 1996.

Electric vehicle testing conducted by the Program includes baseline performance testing (EV America testing), accelerated reliability (life-cycle) testing, and fleet testing. The baseline performance parameters include acceleration, braking, range, energy efficiency, and charging time. The Program collects accelerated reliability and fleet operations data on electric vehicles operated by the Program's Qualified Vehicle Testing (QVT) partners. The Program's QVT partners have over 3 million miles of electric vehicle operating experience. The QVTs are

- Southern California Edison
- Salt River Project
- Potomac Electric Power Company
- Electric Transportation Applications
- Arizona Public Service.

Through the Field Operations Program, DOE provides incremental funding to federal agencies that lease electric vehicles.

In conjunction with six electric utility partners, DOE also makes electric vehicle loaners available to federal agencies, within the utility partners' respective territories. The six electric utilities loaning vehicles to federal fleets are

- Virginia Power
- Southern California Edison
- San Diego Gas and Electric
- Potomac Electric Power Company
- Georgia Power
- Boston Edison.

Test results and Program information are available via the Program's World Wide Web site <http://ev.inel.gov/sop>.



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# **Field Operations Program Activities Status Report Fiscal Years 1997 through mid-1999**

## **1. INTRODUCTION**

This report summarizes the activities of the Field Operations Program since its inception in fiscal year 1997 through mid-fiscal year 1999. The goals of the Field Operations Program include the field evaluation of electric vehicles in real-world applications and environments; the advancement of electric vehicle technologies; the development of infrastructure elements necessary to support significant electric vehicle use; and increasing the awareness and acceptance of electric vehicles by the public.

The Field Operations Program's focus includes three major and concurrent electric vehicle testing activities. The first is the baseline performance testing of electric vehicles that are offered for sale or leasing by original equipment manufacturers. The Baseline Performance testing is also known as EV America testing. This name was originally used when the Baseline Performance testing was performed under the Site Operator Program in conjunction with an electric utility group known as EV America.

The second activity consists of Accelerated Reliability testing of electric vehicles and the collection and dissemination of operating performance parameters. Vehicles subjected to Accelerated Reliability testing are operated by electric utilities with the goal of placing 25,000 miles on individual vehicles within one year. Since the normal fleet vehicle is only driven approximately 6,000 miles per year, this type of an operations mode allows an accelerated life-cycle analysis of vehicles.

The third testing activity consists of field operations testing of electric vehicles and the collection and dissemination of operating performance parameters such as energy use, charging events, and mileage. The vehicles are operated in normal electric utility fleet applications such as for meter reading.

Through a competitive bid process, the Program contracted with electric utilities that became the Program's Qualified Vehicle Testers (QVTs). All three of the above testing activities are conducted at the QVT locations. The QVTs are:

- Arizona Public Service
- Electric Transportation Applications
- Potomac Electric Power Company
- Salt River Project
- Southern California Edison.

To support the use of electric vehicles in federal fleets, DOE has implemented two new activities. The first is a National Loaner Program that provides loaner electric vehicles to interested federal fleets on a trial basis. In the second activity, DOE provides 50% of the incremental cost (up to \$10,000 per vehicle) when federal fleets lease electric vehicles.

The Field Operations Program continues to support the infrastructure development activities of the National Electric Vehicle Infrastructure Working Council and the International Energy Administration.

Personnel of the Idaho National Engineering and Environmental Laboratory (INEEL) manage the Field Operations Program. The principal management functions include the following:

- Technical and financial monitoring of programmatic activities, including periodic progress reports to DOE.
- Data acquisition, analysis, and dissemination. The data from the Field Operations Program is made available to interested parties through Program talks at conferences and to public meetings as well as through the INEEL's World Wide Web site at <http://ev.inel.gov/sop>
- Coordination of Program efforts in the areas of public awareness and infrastructure development (program-related meetings, and educational presentations).

This Status Report contains the following:

- A section providing specific information concerning the Qualified Vehicle Testers, their overall interests, and their programmatic activities.
- A general discussion of electric vehicle performance testing results and an indication of performance testing trends over the years 1997, 1998, and 1999.
- Several sections discussing in greater detail the National Loaner and Incremental Funding Programs, as well as other Field Operations Program activities.

## **2. BACKGROUND**

The Field Operations Program and its predecessor, the Site Operator Program, were established by the Department of Energy (DOE) to incorporate the electric vehicle activities dictated by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976. In the ensuing years, the Program evolved in response to new legislation, interests, and technologies. Since its inception in 1976 as the Site Operator Program, a commercialization effort was intended, but this was not feasible for lack of vehicle suppliers and infrastructure. By 1996, the Site Operator Program comprised over 250 vehicles, of which about 50 were latest generation vehicles. DOE partially funded the participant's Program expenditures and the INEEL received operating and maintenance data. Program participant efforts reflected varying combinations of day-to-day use, laboratory testing and evaluation, and successful promotion of public awareness by demonstrations, exhibits, and media dissemination of related activities and information. The Site Operator Program ended in September 1996, when it was superseded by the Field Operations Program.

Program direction changed with the inception of the Field Operations Program. Commercial vehicles from original equipment manufacturers became available for testing and deployment, and the Program was able to focus on supporting the goal of commercial deployment of electric vehicles.

During 1996, the Field Operations Program requested and received proposals from interested groups to become qualified vehicle testers (QVTs). This formal procurement process resulted in the selection of two groups of QVTs. One QVT is headed by Southern California Edison (SCE), a California-based electric utility. The other group is headed by Electric Transportation Applications (ETA) of Arizona, and includes the electric utilities Arizona Public Service, Potomac Electric Power Company, and the Salt River Project. These QVTs share 50% of the cost of all vehicle testing activities. The QVTs have conducted all the Baseline Performance, Accelerated Reliability, and Fleet Vehicle testing. The next several pages describe the QVTs and their electric-vehicle-related activities.



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**Background** Arizona Public Service (APS) is Arizona's principal electric energy supplier. APS, a successor to a series of small utility operations originating in 1886, was incorporated in 1920 under the laws of Arizona and has operated under its present name since 1952. The Company serves a rapidly growing market, meeting the electricity needs of approximately 705,000 customers in an area that includes 11 of Arizona's 15 counties.

In 1979, APS began their involvement in the field of electric vehicles with the purchase of a Mars Renault. Now, 41 vehicles and over 750,000 miles later, APS continues to further electric vehicles through cutting edge research, education, and competition.

**Projects** The object of the APS Electric Vehicle Program is to test and evaluate the viability of electric vehicles in fleet use through the collection of operation, maintenance and battery data. This program also evaluates infrastructure safety and effectiveness, particularly in the area of battery charging. Information collected is shared with the U.S. Department of Energy, and other interested parties, to promote electric vehicle use in commercial fleets.

APS's current electric vehicle fleet includes eleven General Motors EV1s, six Solectria E-10s, two Chevrolet Electric S-10s, two Ford Electric Rangers, and one Chrysler Mini Van. These vehicles are assigned to Executive staff, Meter Readers, and Research and Development departments. Information is collected on vehicles to assess overall vehicle performance.

In 1995, APS recognized that the usefulness of electric vehicles in fleets is highly dependent on the vehicle range, consistency, and cost. In 1996, APS initiated its Charger Test Project to address these items. The project included chargers from Norvik, GM-Hughes, and Solectria and vehicles from Solectria and US Electricar. Conclusions showed that battery range and life are directly related to the use of fast charging. The conclusions from this project have warranted further investigations into the use of fast charging to extend battery life. APS is currently focused on the development of fast charging for fleet applications.

APS is also involved in furthering education through the sponsorship of several Arizona high schools in the conversion of combustion engine vehicles to electric power. Through this program, students convert their vehicles and compete against other schools in an effort to promote electric vehicle technology.

In 1990, APS began their title sponsorship of the APS Electrics which has since become an international event with coverage from Canadian and Japanese magazines and journals. The event attracts participants from across the United States and Canada to compete in a variety of racing divisions. Through this competition APS promotes electric vehicle awareness and education.

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## *Electric Transportation Applications*

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**Background** Electric Transportation Applications (ETA) is composed of professional advisors and consultants with extensive experience in electric vehicle acquisition and the infrastructure requirements to support EV development and deployment. ETA offers a complete array of fleet services to private and government fleet managers and purchasers of electric vehicles, providing analysis, design, engineering, specification, testing, and infrastructure to support electric vehicle fleets. ETA will analyze objectives and options and recommend alternatives. ETA offers a full range of services from analysis to implementation and management of operations.

ETA's experience includes extensive work with educational institutions, from student programs to technical seminars. ETA communicates with numerous educational institutions, manufacturers, government agencies and scientists world wide disseminating electric vehicle experience among vehicle users, saving costly experimentation and failure. ETA work results are widely published in industry literature and frequently presented at industry conferences including those of the Society of Automotive Engineers, the Institute of Electrical and Electronic engineers, the Edison Electric Institute and the Electric Power Research Institute.

**Projects** ETA has developed specifications for purchase of electric vehicles acceptable for utility or government fleet use. The requirements were refined through a consensus process with EV America participating utilities and the U.S. Department of Energy. The requirements have subsequently been used as the national benchmark for electric vehicle performance requirements.

ETA has developed Test Guidelines and Procedures for EV America and the U.S. Department of Energy Field Operations Program. These Guidelines and Procedures are used by ETA for evaluating electric vehicle performance. Testing has been conducted on seventeen converter and OEM electric vehicles and includes both on track and dynamometer testing, as well as testing at various ambient temperatures and states of battery charge. These tests procedures have been adopted by the U.S. Department of Energy as their standard test requirements for electric vehicles.

ETA has coordinated the development of Standard Operating Procedures for fire departments in handling electric vehicle fire and rescue emergencies as well as structure fires and rescue emergencies involving electric vehicle infrastructure. This work included educating fire personnel on the hazards of electric vehicles and assisting in the drafting of standard operating procedures for use in the State of Arizona.

ETA has evaluated the performance of various battery types in a fast charging environment. This work includes the development of special test procedures to evaluate the fleet applicability of battery fast charging. Charge rates of up to 9C (return 50% charge in four minutes) have been evaluated to determine the feasibility of centralized

fueling for electric vehicles. Results of this work have been published nationally and are supported by the Advanced Lead-acid Battery Consortium.

ETA has developed safety plans for the conduct of electric vehicle races. These plans include vehicle design requirements, charging requirements, logistics, emergency planning, and training. The plans and training have been utilized to conduct races across the United States.

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**Background** Potomac Electric Power Company (PEPCO) is an investor-owned electric utility serving the electricity needs of 1.9 million people in the Washington DC metropolitan area. PEPCO's 640 square mile service territory includes the District of Columbia, and major portions of Montgomery and Prince George's counties in Maryland. PEPCO also sells electricity at wholesale to Southern Maryland Electric Cooperative, Inc.

PEPCO's electric vehicle program focuses on the areas of demonstration and public awareness, as well as the development of fleet applications for electric vehicles in the Washington DC area. PEPCO has established special electric vehicle rates for each of its two jurisdictions. For the District of Columbia, the experimental electric vehicle time-of-use rate is 2.795 cents per kilowatt hour in the summer and 2.705 cents per kilowatt hour in the winter. In Maryland, PEPCO has an experimental electric vehicle time-of-use rate of 2.512 cents per kilowatt hour.

**Projects** PEPCO initiated an Electric Vehicle Lease Program in 1997, beginning with the Federal Government (General Services Administration) as a customer. Originally, the lease program with GSA consisted of PEPCO leasing ten electric Chevy S-10s to the GSA under an area-wide utility agreement. PEPCO has also initiated contact with and has responded to inquiries from other fleet customers, both private and government, with regard to leasing electric vehicles. For example, in response to the Department of the Interior, PEPCO installed a charger at the Rock Creek Park and provided the Park Service with an electric Chevy S-10 to try out as a free loaner vehicle for a month. In addition, PEPCO is working with the U.S. Department of Energy and Ford Motor Company to put together an electric vehicle loaner/lease plan with incentives to assist interested area fleets in acquiring Ford Ranger electric vehicles. PEPCO also leases an electric truck to the Architect of the Capitol.

PEPCO is committed to helping automobile manufacturers acquaint potential customers with electric vehicles. To facilitate this, PEPCO has hosted joint marketing activities with automobile manufacturers, helping the OEMs display their electric vehicles to local fleet managers and also assisting in the coordination of Ride and Drives for fleet managers and the general public.

PEPCO purchased five electric S-10 pickup trucks in 1997. One vehicle has been leased to the Southern Maryland Electric Cooperative, two are being tested by the U.S. Department of Energy in Arizona, and two are being used in the PEPCO fleet. Also in

the fall of 1997, PEPCO initiated negotiations with both Toyota and Ford with regard to purchasing at least 15 electric RAV4s and Ford Rangers for the PEPCO fleet.

Working jointly with the U.S. Department of Energy through its Field Operations Program, PEPCO is helping to test electric vehicles for commercial fleet use. There are more than 1,350 commercial and government fleets in the Washington area with about 150,000 vehicles. PEPCO has committed to the development of electric vehicle infrastructure at the Anacostia Navy Station to support 30 electric Chevy S-10s purchased by the Navy. The Anacostia Navy Transportation Department is an authorized GM service center for EVs.

PEPCO is working with other industry leaders to commercialize EV technology on behalf of the electric utility industry by serving as program manager of EV America. EV America is a utility-sponsored group that is helping to introduce a large number of electric vehicles in fleet application in significant areas of the country. The mission of EV America is to develop a self-sustaining market for electric vehicles. A key component of the EV America program is the establishment of a partnership between the electric utility industry and the federal government.

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**Background** Salt River Project began in 1903 as the Salt River Valley Water User's Association to take advantage of the 1902 Newlands Reclamation Bill in the United States Congress, becoming the first project of the Bureau of Reclamation with the construction of Roosevelt Dam.

In 1936, the Association began their Agricultural & Improvement District to make use of the potential of the dams on the Salt and Verde Rivers to make electricity. Since that time SRP has grown to become the nation's 5th largest municipal electric utility serving 680,000 people in 1998.

SRP began its electric vehicle program in 1991 with the purchase of four G-Vans. Since then, SRP has gone over 150,000 miles in electric cars. For over six years, SRP's EV Program has spanned a wide array of activities. They include educational, demonstration, and public information initiatives, as well as market and infrastructure research. With Arizona's first Norvik *MinitCharger*®, the program's focus has been researching the effects of fast charging EVs. SRP is considered a pioneer and leader in this field.

**Projects** In 1992, SRP began their sponsorship of two high schools to build an electric vehicle. SRP currently offers 10 school sponsorships of \$5,000 annually to schools in its service territory to convert combustion engine vehicles to electric. This sponsorship is seen as a partnership to assist in the promotion of electric vehicle interest and confidence in the field of EVs among high school students. Since its beginning, SRP has helped make possible the conversion of over 30 vehicles to electric power.

SRP's electric vehicle fleet currently includes three US Electricars, three Electric Ford Rangers, two US Electricar Eprizms, two General Motors EV1s, one Ford probe and one Chrysler TeVan. These electric vehicles are used on a daily basis as part of SRP's Pool, Survey and Demonstration Vehicles, and as part of Marketing and Public Relations.

SRP supported EVRN's "Electric Vehicle Fast Charging in Fleet Applications Study" to determine the feasibility of using fast charge fueling depots in a fleet environment. Four US Electricars were assigned to people in different departments and fueled using only fast-charging. Results demonstrated the effectiveness of a fast-charge fueling depot and concluded that a network of strategically located fast charge stations would tremendously enhance the performance of fleet EVs.

In January 1997, SRP installed their first Electric Vehicle Charger at their Project Administration Building. This inductive charger is manufactured by Huhes-Delco and is compatible with the General Motors EV1. Four other inductive chargers have been installed at various other SRP Facilities.

In the Spring of 1998, SRP installed another EV charging device compatible with the Electric Ford Ranger. This Power Control Station (PCS) is manufactured by SCI and is fitted with two Electric Ranger compatible Avcon connectors. The Avcon connectors can be changed out to be compatible with most conductively charged electric vehicles. Other PCS installations will take place in 1998 at five other SRP facilities.

To support the growing population of electric vehicles in the Phoenix Metropolitan area, SRP, in conjunction with other local companies, has designed and installed a network of public charging stations. These stations provide both inductive and conductive charging opportunities of electric vehicle owners. By 1998, eight public charging stations had been installed in strategically located areas throughout the valley including Scottsdale Fashion Square, Arizona Mills, Biltmore Fashion Square and Fiesta Mall.

In March 1998, SRP participated in the APS Electrics electric vehicle race at Firebird International Raceway. SRP's Electric Ford Probe took first place in the Super/Street Stock Feature Race. The Probe uses a 150 kW AC Propulsion Controller and 28 Optima Yellow tops batteries. This was SRP's second consecutive first place finish in the race.

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An *EDISON INTERNATIONAL* Company

**Southern California Edison**  
**Electric Transportation Division**

**Utility Fleet Integration of Evs  
and EV Technical Center Services**

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**Background** Southern California Edison's (SCE) Electric Transportation (ET) Division was created in 1991 to develop a safe, reliable, efficient and cost-effective electric supply system for the future use of electric vehicles (EVs) and other electric-drive technologies in its service territory. The ET Division is organized into two basic areas: business planning/compliance and the Pomona EV Technical Center. These areas focus on strategic planning, consumer education, EV and battery testing, and infrastructure. They are designed to support the emergence and growth of viable electro-drive technologies in a manner that is an economic benefit to utility customers and shareholders.

**Projects** *EV Fleet and Edison*

**Leadership:** SCE introduced EVs into its fleet in 1988 with two prototype G-Vans. Since then, vehicles have been added at an increasing pace every year. Today, SCE operates and maintains an active fleet of over 250 EVs.

**State of the Art:** The SCE fleet features the most technologically advanced EVs available; nearly one-half of the fleet was delivered during the past 12 months. It comprises Chevrolet *S-10* and Ford *Ranger* pickups, General Motors *EV1s*, Honda *EV PLUS*, Nissan *Altras*, and Toyota *RAV4s*, as well as a few prototype and conversion vehicles. Several original equipment manufacturers selected SCE to evaluate their prototype EVs in a large fleet environment. Southern California Edison was among the first of only a few utilities in North America to test the Nissan *Altra*, Chrysler *EPIC*, and fast-charge Chevrolet *S-10*.

**Fleet Use:** Some of SCE's fleet EVs are used exclusively for research and public education, the majority of vehicles are used daily in "real world" service. Fleet applications include vehicles used by meter readers, service managers, field representatives, service planners, mail handlers, security patrols and carpools. As of early 1999, the fleet had logged about 1.6 million miles.

**Testing:** SCE continuously monitors its fleet's operational and maintenance performance. Information collected and calculated includes average trip length, cumulative mileage, vehicle usage, charging patterns, AC energy consumption, and battery life.

### ***Future Fleet Developments***

SCE continues to expand its EV fleet, additional purchases are in progress, including the *EVI* powered by nickel metal-hydride (NiMH) batteries, the inductively charged *RAV4*, and the Chrysler *EPIC*. The utility plans to add 125 EVs by year-end 1999. SCE is integrating into its fleet advanced batteries, including NiMH and lithium-ion. SCE also anticipates that it will use in its fleet a number of vehicles outfitted with USABC advanced batteries such as lithium-polymer.

### ***EV Technical Center***

At SCE's recently expanded Electric Vehicle Technical Center, the utility is working with technology developers and manufacturers, individual and fleet customers, policy makers and regulatory agencies to test and evaluate a variety of infrastructure options, battery types, and electrotechnology designs to determine optimum equipment and charging use. The results of these tests help SCE and other businesses involved in electro-drive technology develop better products, assess the impact of this technology on the utility system, and prepare the public for emerging markets.

The EV Tech Center provides a variety of test and evaluation services, carried out by a staff of highly qualified mechanics, technicians and engineers. Primary services include vehicle testing on SCE's "Pomona Loop," a 20-mile urban driving route, and the nearby Pomona Raceway, as well as battery and EV charger testing. To ensure quality data and achieve efficiencies in data collection and analysis, SCE uses the ABB "Alpha kWh Meter." Also tested are a wide range of "non-road" EVs such as ground support equipment for airports, electric forklifts, "burden carriers" etc... In addition, the EV Tech Center performs EV maintenance, repairs, training, and fleet utilization evaluation.

SCE's customer-tailored classes for EV professionals and operators include proper battery charging and maintenance procedures, component testing, vehicle characterization, data acquisition, driving characterization, diagnostics and safety.

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### 3. BASELINE PERFORMANCE (EV AMERICA) TESTING

During the early 1990s, electric vehicle performance claims were subject to significant uncertainty. In an effort to reduce the uncertainty, EV America and the U.S. Department of Energy's Site Operator Program sponsored independent electric vehicle performance tests using a uniform set of testing protocols. These tests have continued under the Field Operations Program, and include parameters such as acceleration, range, braking, and charging time. The 1997, 1998, and 1999 Baseline Performance test results are available at the end of this chapter as vehicle fact sheets. During 1999, the Program will complete Baseline Performance testing on at least two new vehicles equipped with advanced battery packs. Additional test results are available in the *Site Operator Program Final Report* (January 1998, INEEL/EXT-97-01383). That report and other EV information may be obtained at the Program's website; the address is:

<http://ev.inel.gov/sop>

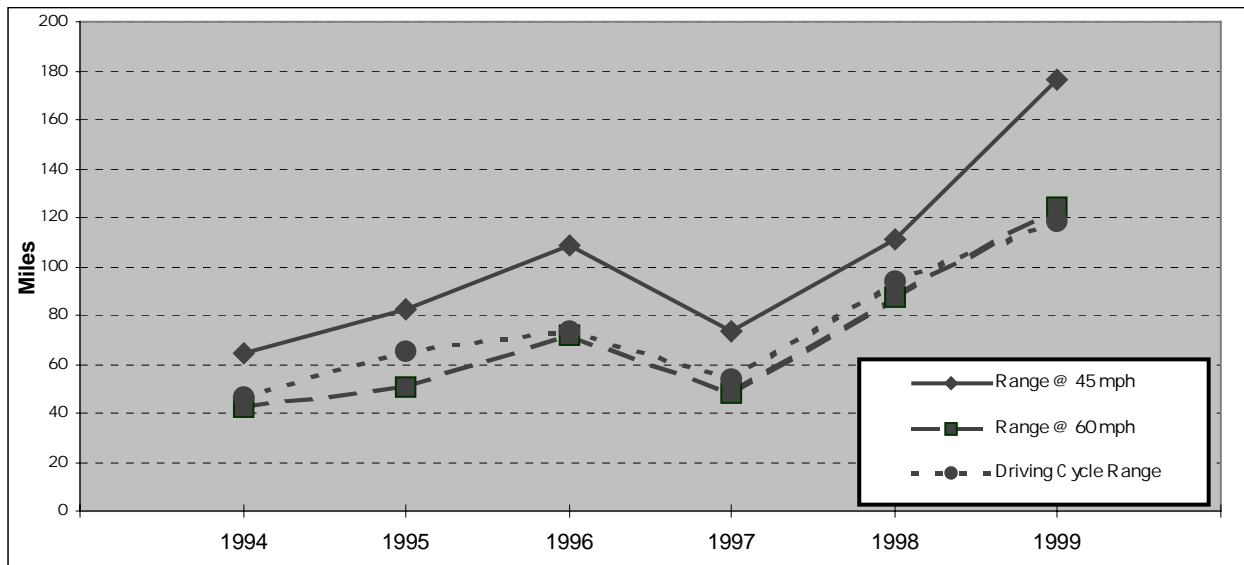
Electric Transportation Applications, in conjunction with EV America, foreign and domestic original equipment manufacturers, vehicle converters, DOE, and other electric utility groups, developed the baseline performance testing procedures. Vehicles to be tested must first meet minimum qualification standards, and all of the vehicle testing has been performed to stringent testing procedures. All this helps the potential purchaser of electric vehicles to have greater confidence that her or his expectations of vehicle performance will be met if a vehicle passes the baseline performance tests. The complete test procedures are available at the above internet address.

The Baseline Performance testing continues to serve as an independent source of electric vehicle analysis to the potential purchaser or lessee of electric vehicles. The testing provides the vehicle user with a nonbiased analysis, that has not always closely paralleled the vehicle provider's stated performance claims.

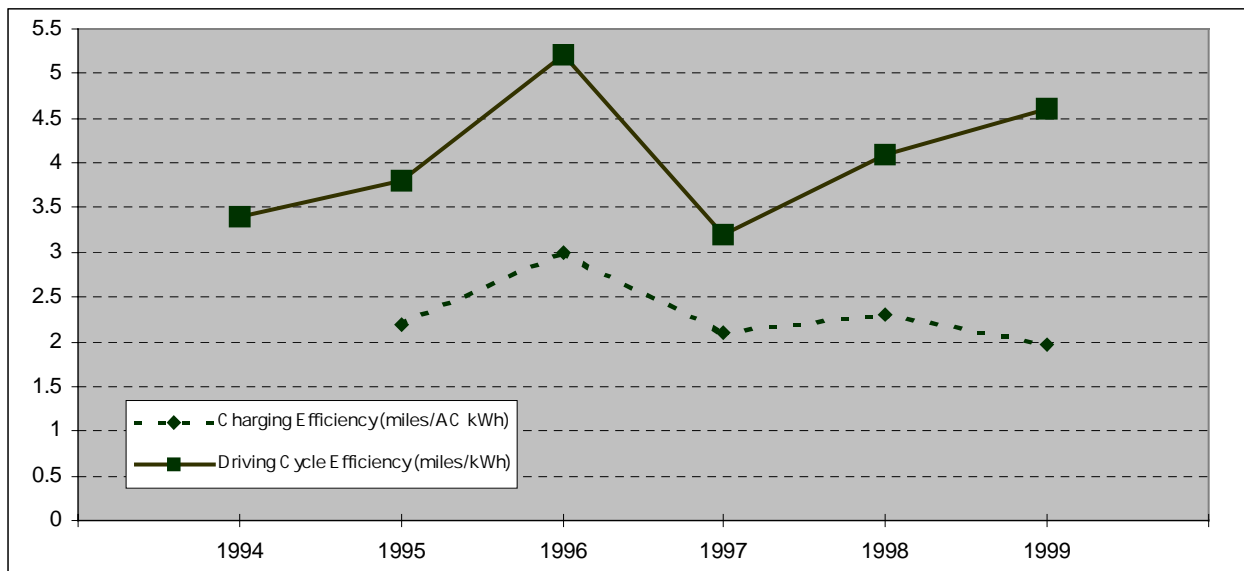
The testing results demonstrate continuous improvements in performance characteristics both on a year-to-year basis and over the entire 6-year testing history. For instance, all three types of range tests (Figure 1) show overall increases in range for each test year with the exception of the 1997 test vehicles. However, both of the 1997 vehicles were pickup trucks. With an average payload of 825 pounds, both of the pickup truck (Chevrolet S-10 and Ford Ranger) payloads exceeded all but one of the previously tested vehicle's payloads, some by more than double. The 1998 Toyota RAV4's drive cycle range is more than double the average range for the 1994 vehicles. All three of the average range results for the 1999 test vehicles (EV1 and S-10 with NiMH batteries) is farther than all of the respective 1994 and 1995 averages combined.

Generally, the increases in range are a result of increases in the amount of onboard energy storage as well as increases in the energy efficiencies. The results of both the charging efficiency tests and the driving cycle range tests (SAE J1634) show the correlation that changes in energy efficiencies (Figure 2) have with changes in range (Figure 1). The 1996 energy efficiency testing results are mostly driven by the General Motors EV1, which demonstrated a driving cycle energy efficiency of 8.7 miles per kWh and a charging efficiency of 4 miles per AC/kWh. Figure 3 shows the overall increase in vehicle energy from 1994 through 1999, which can also be compared to changes in range (Figure 1).

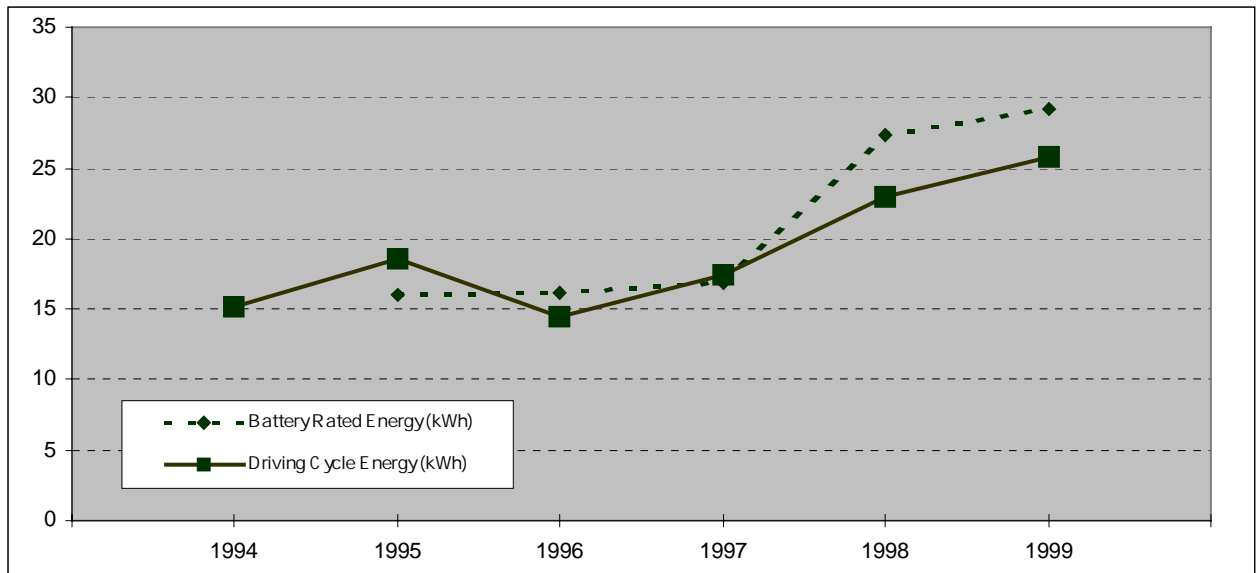
Figure 4 shows the acceleration, maximum speed, and recharging time performance improvements achieved throughout the 6 years of testing. The average time required to recharge the battery packs has decreased on average, while the average maximum speed has increased. The average time required to accelerate from 0 to 50 mph has generally improved over the test period.



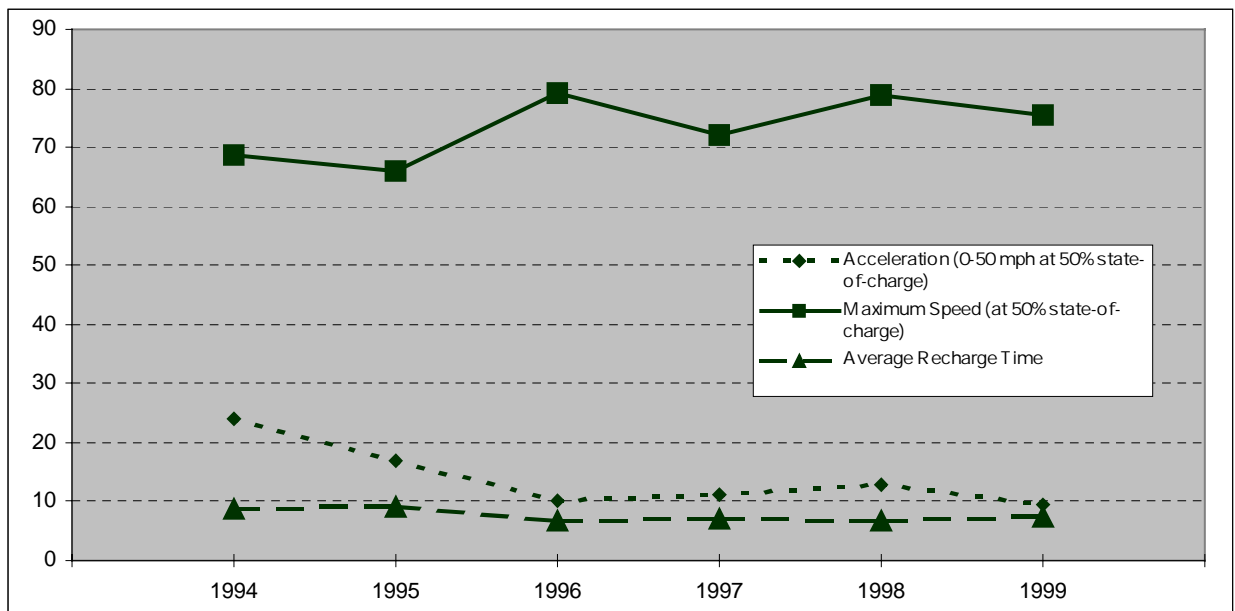
**Figure 1.** Baseline Performance (EV America) range test results (in miles) for constant-speed tests at 45 and 60 mph and range test results for the SAE J1634 driving cycle test. The figure shows the average results for all vehicles tested during each year.



**Figure 2.** Baseline Performance (EV America) energy efficiency test results for the charging efficiency test and the SAE J1634 driving cycle test. The figure shows the average results for all vehicles tested during each year. The charging efficiency test was not performed on the 1994 tested vehicles.



**Figure 3.** The Battery Rated Energy (kWh) line is the average manufacturer-specified battery energy in kilowatt-hours. The manufacturer-specified energy could not be calculated for the 1994 test vehicles because the manufacturer-specified amp-hours was not available. The Driving Cycle Energy (kWh) line is the average total energy used for the drive cycle range tests.



**Figure 4.** Baseline Performance (EV America) test results for acceleration in seconds, maximum speed in mph at 50% state of charge (SOC), and recharge time in hours. The plotted results are the average test results for all vehicles tested during each respective year.

As a reference, Table 1 lists the vehicles that have undergone Baseline Performance testing since its inception during 1994. The following fact sheets summarize the test results for the vehicles Baseline Performance tested since 1997. Fact sheets for all vehicles Baseline-Performance tested since 1994 are available on the Field Operations Program web site.

**Table 1.** All vehicles Baseline Performance (EV America) tested since 1994.

<b>Manufacturer</b>	<b>Model</b>	<b>Type</b>	<b>Battery</b>	<b>Battery type</b>
<b>Tested 1999</b>				
General Motors	1999 EV1	Sport coupe	Ovonic Energy Products	Nickel-metal hydride
Chevrolet	1998 S-10	Pickup	Ovonic Energy Products	Nickel-metal hydride
<b>Tested 1998</b>				
Toyota	1998 RAV4	Sport utility vehicle	Panasonic	Nickel-metal hydride
<b>Tested 1997</b>				
Ford	1998 Ranger	Pickup	Delphi	Lead-acid
Chevrolet	1997 S-10	Pickup	Delphi	Lead-acid
<b>Tested 1996</b>				
General Motors	1997 EV1	Sport coupe	Delphi	Lead-acid
Toyota	1996 RAV4	Sport utility vehicle	Matsushita	Lead-acid
<b>Tested 1995</b>				
Solectria	1995 Force	Sedan	GM Ovonic	Nickel-metal hydride
Solectria	1994 E10	Pickup	Hawker	Lead-acid
Baker	1994 EV100	Pickup	GM Ovonic	Nickel-metal hydride
<b>Tested 1994</b>				
BAT International	1994 Metro	Sedan	Optima	Lead-acid
BAT International	1994 Metro	Sedan	Trojan	Lead-acid
BAT International	1994 Pickup	Pickup	Trojan	Lead-acid
Dodge	1994 Caravan	Van	Eagle-Picher	Nickel Iron
Solectria	1994 Force	Sedan	Hawker Energy	Lead-acid
Solectria	1994 E10	Pickup	Hawker Energy	Lead-acid
Unique Mobility	1994 Pickup	Pickup	Optima	Lead-acid
U.S. Electricar	1994 Sedan	Sedan	Hawker Energy	Lead-acid
U.S. Electricar	1994 Pickup	Pickup	Hawker Energy	Lead-acid



## 1999 GENERAL MOTORS EV1 w/NiMH

### VEHICLE SPECIFICATIONS

#### PURPOSE-BUILT VEHICLE

Base Vehicle: 1999 EV1 NiMH

VIN: 4G5PX2256X00076

Seatbelt Positions: Two

Standard Features:

Cruise Control      Dual Airbags  
Power Steering      Traction Control  
Daytime Running Lamps  
Power Windows, Mirrors & Door Locks  
AM/FM Stereo w/Cassette and CD Player  
Regenerative Braking with Coastdown  
Electro-Hydraulic Braking with ABS  
Electro Windshield Defogger & De-Icer  
Lightweight Bonded Aluminum Structure  
Check Tire Pressure System  
High Voltage Isolation Assurance  
Heat Pump Climate Control System w/Pre-Conditioning Feature  
Electronic Key Pad Entry/Activation

#### BATTERY

Manufacturer: Ovonic Energy Products

Type: Nickel Metal Hydride

Number of Modules: 26

Weight of Module: 18.3 kg

Weight of Pack(s): 481 kg

Pack Locations: Integral T-Pack

Nominal Module Voltage: 13.2 V

Nominal System Voltage: 343 V

Nominal Capacity (C/2): 85 A/H

#### WEIGHTS

Design Curb Weight: 2,970 lbs

Delivered Curb Weight: 2,848 lbs

Distribution F/R: 53/47 %

GVWR: 3410 lbs

GAWR F/R: 1705/1705 lbs

Payload: 440 lbs

Performance Goal: 400 lbs

#### DIMENSIONS

Wheelbase: 98.9 inches

Track F/R: 57.9/49.0 inches

Length: 169.7 inches

Width: 69.5 inches

Height: 50.5 inches

Ground Clearance: **4.3 inches at GVWR**

Performance Goal: 5.0 inches at GVWR

#### CHARGER

Location: Off-Board

Type: Magne Charge Inductive 6.6 kW

Input Voltages: 191 - 256 VAC

#### TIRES

Tire Mfg: Michelin

Tire Model: Proxima RR™ Radial

Tire Size: P175/65R14

Tire Pressure F/R: 50/50 psi

Spare Installed: No; Self Sealing Tires

#### TEST NOTES:

- At test termination vehicle was still able to maintain required drive schedule.
- Testing was terminated upon illumination of the Service Now TellTale.
- As detailed in the Owners Manual, the Battery Life, Reduced Performance, Service Soon and Service Now telltales illuminated during the drive schedules.
- On 3% Grade, this vehicle completed 67 minutes 9 seconds from 100% SOC.
- Standing water test was conducted in 6" versus 8" identified in procedure.
- GM provided instrumentation connections, a 100:1 voltage divider and battery pack thermocouple.
- Vehicle was removed from Test Program for one 24-hour repair period to replace a battery module.

This Vehicle meets all EV America Minimum Requirements listed on back. Values in **red** indicate the Performance Goal was not met. All Power and Energy values are DC unless otherwise specified.

#### ACCELERATION 0-50 mph

At 100% SOC: 6.3 sec

At 50% SOC: 7.9 sec

Max. Power: 104 kW

Performance Goal: 13.5 sec at 50% SOC

#### MAXIMUM SPEED @ 50% SOC

At 1/4 Mile: 78.3 mph

At 1 Mile: 79.6 mph

Performance Goal: 70 mph in one mile

#### CONSTANT SPEED RANGE @ 45 mph<sup>1,2,3</sup>

Range: 220.7 miles

Energy Used: 28.15 kWh

Average Power: 5.81 kW

Efficiency: 127 Wh/mile

Specific Energy: 58.5 Wh/kg

#### CONSTANT SPEED RANGE @ 60 mph<sup>1,2,3</sup>

Range: 160.6 miles

Energy Used: 27.04 kWh

Average Power: 10.28 kW

Efficiency: 168 Wh/mile

Specific Energy: 56.2 Wh/kg

#### DRIVING CYCLE RANGE<sup>1,2,3</sup>

Range per SAE J1634: 140.3 miles

Energy Used: 25.14 kWh

Average Power: 5.28 kW

Efficiency: 179 Wh/mile

Specific Energy: 52.3 Wh/kg

Performance Goal: 60 miles

#### BRAKING FROM 60 mph

Controlled Dry: 160.0 feet

Controlled Wet: 185.4 feet

Panic Wet: 172.4 feet

Course Deviation: 0.0 feet

#### HANDLING

Avg Time @ 90% SOC: 55.1 sec

Avg Time @ 50% SOC: 54.4 sec

Avg Time @ 20% SOC: 54.3 sec

Avg Dodge Neon Time: 54.6 sec

#### GRADEABILITY (Calculated)

Maximum Speed @ 3%: 78.8 mph

Maximum Speed @ 6%: 78.3 mph

Maximum Grade: 56.9%

Time on 3% Grade: 32 min 25 sec<sup>4</sup>

Performance Goal: 15 Min from 50% SOC

#### CHARGING EFFICIENCY

Efficiency: 373 Wh-AC/mile

Energy Cost: 3.73 ¢/mile

#### CHARGER

Max Charger Ground Current: <0.01 mA

Max Battery Leakage Current: <0.01 MIU

Max DC Charge Current: 13.75 Amps

Max AC Charge Current: 31.86 Amps

Pwr Factor @ Max Current: 0.998

THD(I) @ Max Current: 5.32%

Peak Demand: 6.7 kW

Time to Recharge: 6 Hrs 58 min

Performance Goal: 8 hours

**This vehicle meets the following EV America Minimum Requirements:**

1. Vehicle has a payload of at least 400 pounds.
2. The OEM GVWR has not been increased.
3. The OEM GAWRs have not been increased.
4. Seating capacity is a minimum of (2) occupants.
5. A battery recycling plan has been submitted.
6. The OEM passenger space has not been intruded upon by the electrical conversion materials.
7. The vehicle has a parking mechanism or parking brake as required by 49 CFR 571.105.
8. The vehicle has a minimum range between charges of at least 50 miles when loaded with two 166-pound occupants and operated at a constant 45 mph.
9. The vehicle manufacturer has certified that this vehicle complies with the Federal Motor Vehicle Safety Standards (FMVSS) applicable on the date of manufacture.
10. The vehicle manufacturer has certified the batteries and battery enclosures comply with SAE J1766 and 49 CFR 571.301.
11. Batteries comply with requirements of SAE J1718 and NEC 625 for charging in enclosed spaces without vent fans.
12. The vehicle manufacturer has certified concentrations of explosive gases in the battery box do not exceed 25% of the Lower Explosive Limit (LEL) during and following normal or abnormal charging and operation of the vehicle.
13. The battery charger is capable of recharging the main propulsion batteries to a state of full charge from any state of discharge in less than 12 hours.
14. The vehicle manufacturer has certified the charger is capable of accepting input voltages of 208V and 240V single phase 60 Hertz alternating current service, with a tolerance of +/-10% of rated voltage. Charger input current is compatible with the requirements for Level II chargers and complies with the requirements of SAE J1772. Personnel protection systems are in accordance with UL Proposed Standards 2231-1 and 2231-2.
15. The charger has a true power factor of .95 or greater and a harmonic distortion rated at <= 20% (current at rated load).
16. The charger is fully automatic, determining when "end of charge" conditions are met and transitioning into a mode that maintains the main propulsion battery at a full state of charge while not overcharging it, if continuously left on charge.
17. The vehicle does not contain exposed conductors, terminals, contact blocks or devices of any type that create the potential for personnel to be exposed to 50 volts or greater.
18. The vehicle is accompanied by non-proprietary manuals for parts, service, operation and maintenance, interconnection wiring diagrams and schematics.
19. The vehicle has a state of charge indicator for the main propulsion batteries.
20. Propulsion power is isolated from the vehicle chassis and battery leakage current is less than 0.5 MIU under static conditions.
21. Charging circuits are isolated from the vehicle chassis such that ground current from the grounded chassis any time the vehicle is connected to a charger does not exceed 5 mA in accordance with UL Proposed Standards 2231-1 and 2231-2.
22. Replacement tires are commercially available to the end user.
23. The vehicle is interlocked such that:
  - The controller does not energize to move the vehicle with the gear selector in any position other than "Park" or "Neutral"
  - The start key is removable only when the "ignition key" is in the "Off" position, with the drive selector in "Park"
  - The controller does not initially energize or excite with a pre-existing accelerator input, such that the vehicle can be moved under its own power from this condition.
24. The vehicle manufacturer has certified that the vehicle complies with the FCC requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, "Unintentional Radiators."
25. The vehicle manufacturer has certified failure of a battery or battery pack has deemed to have occurred if the actual battery capacity is not at least 80% of the nominal ampere hour capacity.
26. The vehicle is equipped with an automatic disconnect and a manual service disconnect.
27. The charging system is compatible with the Personnel Protection requirements of SAE J1772.
28. Material Safety Data Sheets (MSDS) have been supplied for all on-board batteries.
29. The level of charge below which the batteries should not be discharged and how the controller automatically limits battery discharge below this level have been identified by the manufacturer.
30. The vehicle manufacturer has verified that the methods(s) of charging the propulsion batteries and the charging algorithm have been reviewed and approved by the battery manufacturer.
31. The charger is capable of meeting the requirements of Section 625 of the National Electric Code(NEC).
32. The vehicle has an on-board vehicle complies with the requirements of 49 CFR 571.301 for fuel-fired heaters.
33. The Battery Energy Management System (BMS).

**This information was prepared with the support of the U.S. Department of Energy (DOE) Award No. DE-FC07-96ID 13475. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.**



## 1998 Chevrolet S-10 Electric w/NiMH

### VEHICLE SPECIFICATIONS

#### PURPOSE-BUILT VEHICLE

Base Vehicle: 1998 S-10  
VIN: 1GCDE14H1W8122580  
Seatbelt Positions: Three  
Standard Features:

Heat Pump Climate Control System; Auxillary  
Diesel Fuel Fired Heater (Only operates Below 37°F)  
Cruise Control  
Power Steering  
Tilt Steering Wheel  
4-wheel Anti-Lock Power Assisted Brakes  
Regenerative Braking  
Propulsion Battery Thermal Management System  
Driver and Passenger-Side Air Bags  
(w/Passenger-Side Deactivation Switch)  
AM/FM Stereo Radio  
Half-Bed Tonneau Cover

#### BATTERY

Manufacturer: Ovonic Energy Products  
Type: Nickel Metal Hydride  
Number of Modules: 26  
Weight of Module: 18.3 kg  
Weight of Pack(s): 490.5 kg  
Pack Locations: Underbody  
Nominal Module Voltage: 13.2 V  
Nominal System Voltage: 343 V  
Nominal Capacity (C/2): 85 Ah

#### WEIGHTS

Design Curb Weight: 4200 lbs  
Delivered Curb Weight: 4230 lbs  
Distribution F/R: 50/50 %  
GVWR: 5150 lbs  
GAWR F/R: 2700/2900 lbs  
Payload: 950 lbs<sup>5</sup>  
Performance Goal: 600 lbs

#### DIMENSIONS

Wheelbase: 108.2 inches  
Track F/R: 56.9/55.0 inches  
Length: 190.8 inches  
Width: 68.3 inches  
Height: 62.4 inches  
Ground Clearance: 5.2 inches at GVWR  
Performance Goal: 5.0 inches at GVWR

#### CHARGER

Location: Off-Board  
Type: Magne Charge Inductive 6.6 kW  
Input Voltages: 191 - 256 VAC

#### TIRES

Tire Mfg: Uniroyal  
Tire Model: Tigerpaw AWP Radial  
Tire Size: P205/75R15  
Tire Pressure F/R: 50/50 psi  
Spare Installed: No

#### TEST NOTES:

- At test termination vehicle was still able to maintain required drive schedule.
- Testing was terminated upon illumination of the Service Now TellTale.
- As detailed in the Owners Manual, the Battery Life and Service Soon telltales illuminated during the drive schedules.
- On 3% Grade, this vehicle completed 48 minutes 7 seconds from 100% SOC.
- As-delivered Payload was 920 lb.
- General Motors provided instrumentation connections, including a 100:1 voltage divider and battery pack thermocouple.
- Vehicle was removed from Test Program for one 24-hour period to replace a fan control switch.

This Vehicle meets all EV America Minimum Requirements listed on back. Values in **red** indicate the Performance Goal was not met. All Power and Energy values are DC unless otherwise specified.

#### ACCELERATION 0-50 mph

At 100% SOC: 9.9 sec  
At 50% SOC: 10.9 sec  
Max. Power: 98.5 kW  
Performance Goal: 13.5 sec

#### MAXIMUM SPEED @ 50% SOC

At 1/4 Mile: 65.9 mph  
At 1 Mile: 71.0 mph  
Performance Goal: 70 mph in One Mile

#### CONSTANT SPEED RANGE @ 45 mph<sup>1,2,3</sup>

Range: 130.6 miles  
Energy Used: 27.92 kWh  
Average Power: 9.69 kW  
Efficiency: 214 Wh/mile  
Specific Energy: 56.9 Wh/kg

#### CONSTANT SPEED RANGE @ 60 mph<sup>1,2,3</sup>

Range: 87.7 miles  
Energy Used: 27.17 kWh  
Average Power: 18.96 kW  
Efficiency: 310 Wh/mile  
Specific Energy: 55.4 Wh/kg

#### DRIVING CYCLE RANGE<sup>1,2,3</sup>

Range per SAE J1634: 95.3 miles  
Energy Used: 26.35 kWh  
Average Power: 7.69 kW  
Efficiency: 276 Wh/mile  
Specific Energy: 53.7 Wh/kg  
Performance Goal: 60 miles

#### BRAKING FROM 60 mph

Controlled Dry: 177.9 feet  
Controlled Wet: 196.6 feet  
Panic Wet: 194.1 feet  
Course Deviation: 0.0 feet

#### HANDLING

Avg Time @ 90% SOC: 56.0 sec  
Avg Time @ 50% SOC: 56.0 sec  
Avg Time @ 20% SOC: 56.0 sec  
Avg S-10 ICE Time: 58.3 sec

#### GRADEABILITY (Calculated)

Maximum Speed @ 3%: 69.3 mph  
Maximum Speed @ 6%: 66.3 mph  
Maximum Grade: 31.4%  
Time on 3% Grade: 23 min 50 sec<sup>4</sup>  
Performance Goal: 15 Min from 50% SOC

#### CHARGING EFFICIENCY

Efficiency: 794 Wh-AC/mile  
Energy Cost @ 10 ¢/kWh: 7.94 ¢/mile

#### CHARGER

Max Charger Ground Current: <0.01 mA  
Max Battery Leakage Current: <0.01 MIU  
Max DC Charge Current: 13.13 Amps  
Max AC Charge Current: 31.55 Amps  
Pwr Factor @ Max Current: 0.999  
THD(I) @ Max Current: 5.0 %  
Peak Demand: 6.46 kW  
Time to Recharge: **8 Hrs 54 min**  
Performance Goal: 8 hours

**This vehicle meets the following EV America Minimum Requirements:**

1. Vehicle has a payload of at least 400 pounds.
2. The OEM GVWR has not been increased.
3. The OEM GAWRs have not been increased.
4. Seating capacity is a minimum of (2) occupants.
5. A battery recycling plan has been submitted.
6. The OEM passenger space has not been intruded upon by the electrical conversion materials.
7. The vehicle has a parking mechanism or parking brake as required by 49 CFR 571.105.
8. The vehicle has a minimum range between charges of at least 50 miles when loaded with two 166-pound occupants and operated at a constant 45 mph.
9. The vehicle manufacturer has certified that this vehicle complies with the Federal Motor Vehicle Safety Standards (FMVSS) applicable on the date of manufacture.
10. The vehicle manufacturer has certified the batteries and battery enclosures comply with SAE J1766 and 49 CFR 571.301.
11. Batteries comply with requirements of SAE J1718 and NEC 625 for charging in enclosed spaces without vent fans.
12. The vehicle manufacturer has certified concentrations of explosive gases in the battery box do not exceed 25% of the Lower Explosive Limit (LEL) during and following normal or abnormal charging and operation of the vehicle.
13. The battery charger is capable of recharging the main propulsion batteries to a state of full charge from any state of discharge in less than 12 hours.
14. The vehicle manufacturer has certified the charger is capable of accepting input voltages of 208V and 240V single phase 60 Hertz alternating current service, with a tolerance of +/-10% of rated voltage. Charger input current is compatible with the requirements for Level II chargers and complies with the requirements of SAE J1772. Personnel protection systems are in accordance with UL Proposed Standards 2231-1 and 2231-2.
15. The charger has a true power factor of .95 or greater and a harmonic distortion rated at <= 20% (current at rated load).
16. The charger is fully automatic, determining when "end of charge" conditions are met and transitioning into a mode that maintains the main propulsion battery at a full state of charge while not overcharging it, if continuously left on charge.
17. The vehicle does not contain exposed conductors, terminals, contact blocks or devices of any type that create the potential for personnel to be exposed to 50 volts or greater.
18. The vehicle is accompanied by non-proprietary manuals for parts, service, operation and maintenance, interconnection wiring diagrams and schematics.
19. The vehicle has a state of charge indicator for the main propulsion batteries.
20. Propulsion power is isolated from the vehicle chassis and battery leakage current is less than 0.5 MIU under static conditions.
21. Charging circuits are isolated from the vehicle chassis such that ground current from the grounded chassis any time the vehicle is connected to a charger does not exceed 5 mA in accordance with UL Proposed Standards 2231-1 and 2231-2.
22. Replacement tires are commercially available to the end user.
23. The vehicle is interlocked such that:
  - The controller does not energize to move the vehicle with the gear selector in any position other than Park" or "Neutral"
  - The start key is removable only when the "ignition key" is in the "Off" position, with the drive selector in "Park"
  - The controller does not initially energize or excite with a pre-existing accelerator input, such that the vehicle can be moved under its own power from this condition.
24. The vehicle manufacturer has certified that the vehicle complies with the FCC requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, "Unintentional Radiators."
25. The vehicle manufacturer has certified failure of a battery or battery pack has deemed to have occurred if the actual battery capacity is not at least 80% of the nominal ampere hour capacity.
26. The vehicle is equipped with an automatic disconnect and a manual service disconnect.
27. The charging system is compatible with the Personnel Protection requirements of SAE J1772.
28. Material Safety Data Sheets (MSDS) have been supplied for all on-board batteries.
29. The level of charge below which the batteries should not be discharged and how the controller automatically limits battery discharge below this level have been identified by the manufacturer.
30. The vehicle manufacturer has verified that the methods(s) of charging the propulsion batteries and the charging algorithm have been reviewed and approved by the battery manufacturer.
31. The charger is capable of meeting the requirements of Section 625 of the National Electric Code(NEC).
32. The vehicle complies with the requirements of 49 CFR 571.301 for fuel fired heaters.
33. The vehicle has an on-board Battery Energy Management System(BMS).

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## 1998 Toyota RAV4 EV w/NiMH

### VEHICLE SPECIFICATIONS

#### PURPOSE-BUILT VEHICLE

Base Vehicle: 1998 Toyota RAV4

VIN: JT3GS10V0W0001009

Seatbelt Positions: Five

#### Standard Features:

AM/FM Stereo Radio  
Tilt Steering Wheel  
Air Conditioning (Gas Injection Heat Pump)  
Heater (Gas Injection Heat Pump)  
Front Wheel Drive  
Dual Air Bags  
Power Steering (Rack & Pinion, hydraulic)  
Power Brakes  
Four Wheel Disc Brakes  
Four Wheel Anti-Lock Brakes  
Regenerative Braking  
Power Windows Space Saver Spare  
Aluminum Wheels  
Low Rolling Resistance Tires

#### BATTERY:

Manufacturer: Panasonic  
Type: VRLA NiMH  
Number of Modules: 24  
Weight of Module: 18.75 kg  
Weight of Pack(s): 461 kg  
Pack Locations: Underbody  
Nominal Module Voltage: 12 V  
Nominal System Voltage: 288 V  
Nominal Capacity (C/3): 95 Ah

#### WEIGHTS

Design Curb Weight: 3,480 lb  
Delivered Curb Weight: 3,507 lb  
Distribution F/R: 52/48%  
GVWR: 4266 lb  
GAWR F/R: 2,138/2,128 lb  
Payload: 786 lb<sup>1</sup>  
Performance Goal: 600 lb

#### DIMENSIONS

Wheelbase: 94.6 inches  
Track F/R: 57.6/56.9 inches  
Length: 156.6 inches  
Width: 67.1 inches  
Height: 65.0 inches  
Ground Clearance: 6.7 inches at GVWR  
Performance Goal: 5.0 inches at GVWR

#### CHARGER<sup>2</sup>

Location: On-board w/Off-Board PCS  
Type: Conductive  
Input Voltages: 90 to 264 VAC

#### TIRES

Tire Mfg: Bridgestone  
Tire Model: Ecopia EPO2 Radial  
Tire Size: 195/80R16  
Tire Pressure F/R: 44/44 psi  
Spare Installed: Yes

#### TEST NOTES:

8. Design payload value; value as delivered (and tested) was 759 lbs.
9. This vehicle requires a Power Control Station (PCS), which cannot be used with a GFCI protected circuit.
10. All testing was terminated upon receipt of the Flaching SOC telltale.
11. Total range achieved until vehicle could not maintain profile was 116.9 miles.
12. Charge time will be periodically extended 2 hours after a predetermined number of charge cycles has occurred, and when certain battery temperature or voltage conditions exist.
13. On several occasions, charging was impeded due to battery temperature conditions (high dT/dt) .
14. One PCS unit had to be replaced due to inconsistent charging.

This Vehicle meets all EV America Minimum Requirements listed on back.

Values in **red** indicate the Performance Goal was not met.

All Power and Energy values are DC unless otherwise specified.

#### ACCELERATION 0-50 mph

At 100% SOC: 12.8 sec

At 50% SOC: 12.9 sec

Max. Power: 57.3 kW

Performance Goal: 13.5 sec at 50% SOC

#### MAXIMUM SPEED @ 50% SOC

At 1/4 Mile: 63.5 mph

At 1 Mile: 78.8 mph

Performance Goal: 70 mph in one mile

#### CONSTANT SPEED RANGE @ 45 mph<sup>3</sup>

Range: 110.9 miles

Energy Used: 23.34 kWh

Average Power: 9.55 kW

Efficiency: 210 Wh/mile

Specific Energy: 50.8 Wh/kg

#### CONSTANT SPEED RANGE @ 60 mph<sup>3</sup>

Range: 86.9 miles

Energy Used: 27.47 kWh

Average Power: 18.81 kW

Efficiency: 316 Wh/mile

Specific Energy: 59.6 Wh/kg

#### DRIVING CYCLE RANGE<sup>3,4</sup>

Range per SAE J1634: 94.0 miles

Energy Used: 23.01 kWh

Average Power: 6.88 kW

Efficiency: 245 Wh/mile

Specific Energy: 49.9 Wh/kg

Performance Goal: 60 miles

#### BRAKING FROM 60 mph

Controlled Dry: 157.0 feet

Controlled Wet: 183.2 feet

Panic Wet: 200.1 feet

Course Deviation: 0.0 feet

#### HANDLING

Avg Time @ 90% SOC: 59.8 sec

Avg Time @ 50% SOC: 58.8 sec

Avg Time @ 20% SOC: 58.8 sec

Avg S-10 ICE Time: 59.8 sec

#### GRADEABILITY (Calculated)

Maximum Speed @ 3%: 75.4 mph

Maximum Speed @ 6%: 63.6 mph

Maximum Grade: 30.2%

Time on 3% Grade: 21 min 37 sec<sup>3</sup>

Performance Goal: 15 Min from 50% SOC

#### CHARGING EFFICIENCY

Efficiency: 432 Wh-AC/mile

Energy Cost @ 10 ¢/kWh: 4.32 ¢/mile

#### CHARGER

Max Charger Ground Current: <0.01 mA

Max Battery Leakage Current: 0.01 MIU

Max DC Charge Current: 14.51 Amps

Max AC Charge Current: 26.25 Amps

Pwr Factor @ Max Current: 0.828

THD(I) @ Max Current: 8.26%

Peak Demand: 4.45 kW-AC

Time to Recharge: 6 Hrs 47 min

Performance Goal: 8 hours

**The 1998 Toyota RAV4 meets the following EV America Minimum Requirements:**

1. Vehicle has a payload of at least 400 pounds.
2. The OEM GVWR has not been increased.
3. The OEM GAWRs have not been increased.
4. Seating capacity is at least two occupants.
5. A battery recycling plan has been submitted.
6. The OEM passenger space has not been intruded upon by the electrical conversion materials.
7. The vehicle has a parking mechanism or parking brake as required by 49 CFR 571.105.
8. The vehicle has a minimum range between charges of at least 50 miles when loaded with two 166-pound occupants and operated at a constant 45 mph.
9. The vehicle manufacturer has certified that this vehicle complies with the Federal Motor Vehicle Safety Standards (FMVSS) applicable on the date of manufacture.
10. The vehicle manufacturer has certified the batteries and battery enclosures comply with SAE J1766 and 49 CFR 571.301.
11. Batteries comply with the requirements of SAE J1718 and NEC 625 for charging in enclosed spaces without vent fans.
12. The vehicle manufacturer has certified that concentrations of explosive gases in the battery box do not exceed 25% of the Lower Explosive Limit (LEL) during and following normal or abnormal charging and operation of the vehicle.
13. The battery charger is capable of recharging the main propulsion batteries to a state of full charge from any state of discharge in less than 12 hours.
14. The vehicle manufacturer has certified the charger is capable of accepting input voltages of 208V and 240V single phase 60 Hertz alternating current service, with a tolerance of +/-10% of rated voltage. Charger input current is compatible with the requirements for Level II chargers and complies with the requirements of SAE J1772. Personnel protection systems are in accordance with UL Proposed Standards 2231-1 and 2231-2.
15. The charger has a true power factor of .95 or greater and a harmonic distortion rated at < 20% (current at rated load).
16. The charger is fully automatic, determining when "end of charge" conditions are met and transitioning into a mode that maintains the main propulsion battery at a full state of charge while not overcharging it, if continuously left on charge.
17. The vehicle does not contain exposed conductors, terminals, contact blocks or devices of any type that create the potential for personnel to be exposed to 50 volts or greater.
18. The vehicle will be accompanied by non-proprietary manuals for parts, service, operation, maintenance, interconnection wiring diagrams and schematics.
19. The vehicle has a state of charge indicator for the main propulsion batteries.
20. Propulsion power is isolated from the vehicle chassis and battery leakage is less than 0.5 MIU under static conditions.
21. Charging circuits are isolated from the vehicle chassis such that ground current from the grounded chassis any time the vehicle is connected to a charger does not exceed 5 mA in accordance with UL Proposed Standards 2231-1 and 2231-2.
22. Replacement tires are commercially available to the end user.
23. The vehicle is interlocked such that:
  - The controller does not energize to move the vehicle with the gear selector in any position other than "Park" or "Neutral"
  - The start key is removable only when the "ignition key" is in the "Off" position, with the drive selector in "Park"
  - The controller does not initially energize or excite with a preexisting accelerator input, such that the vehicle can be moved under its own power from this condition
24. The vehicle manufacturer has certified that the vehicle complies with the FCC requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, "Unintentional Radiators."
25. The vehicle manufacturer has certified failure of a battery or battery pack has deemed to have occurred if the actual battery capacity is not at least 80% of the nominal ampere hour capacity.
26. This vehicle is equipped with an automatic disconnect and a manual service disconnect.
27. The charging system is compatible with the Personnel Protection requirements of SAE J1772.
28. Material Safety Data Sheets (MSDS) have been supplied for all on-board batteries.
29. The level of charge below which the batteries should not be discharged and how the controller automatically limits battery discharge below this level have been identified by the manufacturer.
30. The vehicle manufacturer has verified that the method(s) of charging the propulsion batteries and the charging algorithm have been reviewed and approved by the battery manufacturer.
31. The charger is capable of meeting the requirements of Section 625 of the National Electric Code (NEC).
32. The vehicle complies with the requirements of 49 CFR 571.301 for fuel fired heaters.
33. The vehicle has an on-board Battery Energy Management System (BMS).

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## 1998 FORD RANGER EV

### VEHICLE SPECIFICATIONS

#### PURPOSE-BUILT VEHICLE

Base Vehicle: 1998 Ford Ranger  
VIN: 1FTCR100XWSA00951  
Seatbelt Positions: Three  
Standard Features:

AM/FM Stereo Radio	Regenerative Braking
Tilt Steering Wheel	Full-Bed Tonneau
Cabin Heat	Cover
Dual Air Bags	Aluminum Wheels
Power Steering	Low Rolling
(Electro-Hydraulic)	Resistance Tires
Power Brakes	Options As Tested
Four Wheel Anti-Lock	Air Conditioning
Disc Brakes	Battery Heater

#### BATTERY

Manufacturer: Delphi  
Type: VRLA  
Number of Modules: 39  
Weight of Module: 19.3 kg  
Weight of Pack(s): 870.1 kg  
Pack Locations: Underbody  
Nominal Module Voltage: 8 V  
Nominal System Voltage: 312 V  
Nominal Capacity (C/2): 60 Ah

#### WEIGHTS

Design Curb Weight: 4,700 lb  
Delivered Curb Weight: 4,731 lb  
Distribution F/R: 51/49%  
GVWR: 5400 lb  
GAWR F/R: 2,659/2,808 lb  
Payload: 700 lb<sup>1</sup>  
Performance Goal: 600 lb

#### DIMENSIONS

Wheelbase: 111.6 inches  
Track F/R: 58.6/57.3 inches  
Length: 187.5 inches  
Width: 69.4 inches  
Height: 66.0 inches  
Ground Clearance: 5.2 inches at GVWR  
Performance Goal: 5.0 inches at GVWR

#### CHARGER

Location: On-board w/Off-Board PCS<sup>2</sup>  
Type: Conductive  
Input Voltages: 187 to 264 VAC

#### TIRES

Tire Mfg: Uniroyal  
Tire Model: Tigerpaw AWP Radial  
Tire Size: P255/70R15  
Tire Pressure F/R: 50/50 psi

#### TEST NOTES:

- Design payload value; value as tested was 669 lb.
- Required Power Control Station (PCS) is purchased separately and cannot be used with a GFCI
- Testing was terminated upon illumination of the Power Limit telltale.
- ICE Vehicle tested was a 1992 rear wheel drive with a 4.3 liter V-6 engine.
- Vehicle completed 21 minutes 54 seconds from 100% SOC.
- Charging time was extended due to high temperature conditions.
- The vehicle's Battery Control Module failed during the Test Program and was replaced
- One battery module failed during the Test Program and was replaced.
- Vehicle was removed from the Test Program for three 24-hour repair periods.

[This Vehicle meets all EV America Minimum Requirements listed on back.](#) Values in **red** indicate the Performance Goal was not met. All Power and Energy values are DC unless otherwise specified.

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#### ACCELERATION 0-50 mph

At 100% SOC: 11.6 sec  
At 50% SOC: 12.3 sec  
Max. Power: 87.4 kW  
Performance Goal: 13.5 sec at 50% SOC

#### MAXIMUM SPEED @ 50% SOC

At 1/4 Mile: 61.6 mph  
At 1 Mile: 74.5 mph  
Performance Goal: 70 mph in one mile

#### CONSTANT SPEED RANGE @ 45 mph

Range: 86.9 miles  
Energy Used: 20.63 kWh  
Average Power: 10.71 kW  
Efficiency: 237 Wh/mile  
Specific Energy: 23.7 Wh/kg

#### CONSTANT SPEED RANGE @ 60 mph

Range: 57.9 miles  
Energy Used: 20.60 kWh  
Average Power: 21.41 kW  
Efficiency: 356 Wh/mile  
Specific Energy: 23.7 Wh/kg

#### DRIVING CYCLE RANGE

Range per SAE J1634: 65.1 miles  
Energy Used: 21.96 kWh  
Average Power: 9.54 kW  
Efficiency: 337 Wh/mile  
Specific Energy: 25.2 Wh/kg  
Performance Goal: 60 miles

#### BRAKING FROM 60 mph

Controlled Dry: 162.8 feet  
Controlled Wet: 202.1 feet  
Panic Wet: 201.1 feet  
Course Deviation: 0.0 feet

#### HANDLING

Avg Time @ 90% SOC: 56.9 sec  
Avg Time @ 50% SOC: 56.8 sec  
Avg Time @ 20% SOC: 56.8 sec  
Avg S-10 ICE Time: 58.3 sec<sup>4</sup>

#### GRADEABILITY (Calculated)

Maximum Speed @ 3%: 68.3 mph  
Maximum Speed @ 6%: 58.1 mph  
Maximum Grade: 34.4%  
Time on 3% Grade: **10 min 48 sec<sup>3,5</sup>**  
Performance Goal: 15 Min from 50% SOC

#### CHARGING EFFICIENCY

Efficiency: 484 Wh-AC/mile  
Energy Cost @ 10¢/kWh: 4.84 ¢/mile

#### CHARGER

Max Charger Ground Current: <0.01 mA  
Max Battery Leakage Current: 0.02 MIU  
Max DC Charge Current: 13.69 Amps  
Max AC Charge Current: 20.92 Amps  
Pwr Factor @ Max Current: 0.989  
THD(I) @ Max Current: 3.30%  
Peak Demand: 4.16 kW-AC  
Time to Recharge: **8 Hrs 51 min<sup>6</sup>**  
Performance Goal: 8 hours

**The 1998 Ford Ranger meets the following EV America Minimum Requirements:**

1. Vehicle has a payload of at least 400 pounds.
2. The OEM GVWR has not been increased.
3. The OEM GAWRs have not been increased.
4. Seating capacity is at least two occupants.
5. A battery recycling plan has been submitted.
6. The OEM passenger space has not been intruded upon by the electrical conversion materials.
7. The vehicle has a parking mechanism or parking brake as required by 49 CFR 571.105.
8. The vehicle has a minimum range between charges of at least 50 miles when loaded with two 166-pound occupants and operated at a constant 45 mph.
9. The vehicle manufacturer has certified that this vehicle complies with the Federal Motor Vehicle Safety Standards (FMVSS) applicable on the date of manufacture.
10. The vehicle manufacturer has certified the batteries and battery enclosures comply with SAE J1766 and 49 CFR 571.301.
11. Batteries comply with the requirements of SAE J1718 and NEC 625 for charging in enclosed spaces without vent fans.
12. The vehicle manufacturer has certified that concentrations of explosive gases in the battery box do not exceed 25% of the Lower Explosive Limit (LEL) during and following normal or abnormal charging and operation of the vehicle.
13. The battery charger is capable of recharging the main propulsion batteries to a state of full charge from any state of discharge in less than 12 hours.
14. The vehicle manufacturer has certified the charger is capable of accepting input voltages of 208V and 240V single phase 60 Hertz alternating current service, with a tolerance of +/-10% of rated voltage. Charger input current is compatible with the requirements for Level II chargers and complies with the requirements of SAE J1772. Personnel protection systems are in accordance with UL Proposed Standards 2231-1 and 2231-2.
15. The charger has a true power factor of .95 or greater and a harmonic distortion rated at < 20% (current at rated load).
16. The charger is fully automatic, determining when "end of charge" conditions are met and transitioning into a mode that maintains the main propulsion battery at a full state of charge while not overcharging it, if continuously left on charge.
17. The vehicle does not contain exposed conductors, terminals, contact blocks or devices of any type that create the potential for personnel to be exposed to 50 volts or greater.
18. The vehicle will be accompanied by non-proprietary manuals for parts, service, operation, maintenance, interconnection wiring diagrams and schematics.
19. The vehicle has a state of charge indicator for the main propulsion batteries.
20. Propulsion power is isolated from the vehicle chassis and battery leakage is less than 0.5 MIU under static conditions.
21. Charging circuits are isolated from the vehicle chassis such that ground current from the grounded chassis any time the vehicle is connected to a charger does not exceed 5 mA in accordance with UL Proposed Standards 2231-1 and 2231-2.
22. Replacement tires are commercially available to the end user.
23. The vehicle is interlocked such that:
  - The controller does not energize to move the vehicle with the gear selector in any position other than "Park" or "Neutral"
  - The start key is removable only when the "ignition key" is in the "Off" position, with the drive selector in "Park"
  - The controller does not initially energize or excite with a preexisting accelerator input, such that the vehicle can be moved under its own power from this condition
24. The vehicle manufacturer has certified that the vehicle complies with the FCC requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, "Unintentional Radiators."
25. The vehicle manufacturer has certified failure of a battery or battery pack has deemed to have occurred if the actual battery capacity is not at least 80% of the nominal ampere hour capacity.
26. This vehicle is equipped with an automatic disconnect and a manual service disconnect.
27. The charging system is compatible with the Personnel Protection requirements of SAE J1772.
28. Material Safety Data Sheets (MSDS) have been supplied for all on-board batteries.
29. The level of charge below which the batteries should not be discharged and how the controller automatically limits battery discharge below this level have been identified by the manufacturer.
30. The vehicle manufacturer has verified that the method(s) of charging the propulsion batteries and the charging algorithm have been reviewed and approved by the battery manufacturer.
31. The charger is capable of meeting the requirements of Section 625 of the National Electric Code (NEC).
32. The vehicle complies with the requirements of 49 CFR 571.301 for fuel fired heaters.
33. The vehicle has an on-board Battery Energy Management System (BMS).

**This information was prepared with the support of the U. S. Department of Energy (DOE) Award No.DE-FC07-96ID 13475. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.**



## 1997 Chevrolet S10 Truck

### Vehicle Specifications

#### PURPOSE-BUILT VEHICLE

Base Vehicle: 1997 Chevrolet S-10

VIN: 1GCD E14H4V80003EX

Seatbelt Positions: Three

Standard Features:

Heat Pump Climate Control System	Power Steering
Auxiliary Diesel Fuel Fired Heater	Power Brakes
(Only operates Below 40 F)	Anti-Lock Brakes
Cruise Control	Front Disk Brakes
Tilt Steering Wheel	Regenerative Braking
Front Wheel Drive	Drivers Side Air Bags
	AM/FM Stereo Radio
	Half-Bed Tonneau Cover

#### BATTERY

Manufacturer: Delphi Energy  
 Type: Valve Regulated Lead-acid  
 Number of Modules: 26  
 Weight of Module: 19 kg  
 Weight of Pack(s): 575 kg  
 Pack Locations: Underbody  
 Nominal Module Voltage: 12 V  
 Nominal System Voltage: 312 V  
 Nominal Capacity (C/2): 48 Ah

#### WEIGHTS

Design Curb Weight: 4,300 lb  
 Delivered Curb Weight: 4,199 lb  
 Distribution F/R: 48/52%  
 GVWR: 5,150 lb  
 GAWR F/R: 2,700/2,900 lb  
 Payload: 951 lb  
 Performance Goal: 600 lb

#### DIMENSIONS

Wheelbase: 108.3 inches  
 Track F/R: 57.2/54.9 inches  
 Length: 188.9 inches  
 Width: 67.8 inches  
 Height: 62.4 inches  
 Ground Clearance: 5.0 inches at GVWR  
 Performance Goal: 5.0 inches at GVWR

#### CHARGER

Location: Off-Board  
 Type: Delco Electronics Inductive 6.6 kW  
 Input Voltages: 165 to 260 VAC

#### TIRES

Tire Mfg: Uniroyal  
 Tire Model: Tigerpaw AWP Radial  
 Tire Size: P205/75R15  
 Tire Pressure F/R: 51/51 psi  
 Spare Installed: No

#### TEST NOTES:

- Vehicle maximum speed is software limited. Chevrolet will be issuing a software modification to allow a maximum speed greater than 70 mph subsequent to completion of EV America Testing.
- ICE Vehicle tested was a 1992 rear wheel drive with a 4.3 liter V-6 engine.
- Vehicle complete 21 minutes 3 seconds from 100% SOC.
- Cruise control failed to engage on two occasions. Vehicle required restart before cruise control could be engaged.
- The battery pack data collection voltage signal was reduced 100:1 through a voltage divider installed by Chevrolet. This was for personnel protection.

[This Vehicle meets all EV America Minimum Requirements listed on back.](#)

Values in **red** indicate the Performance Goal was not met.

All Power and Energy values are DC unless otherwise specified.

#### ACCELERATION 0-50 mph

At 100% SOC: 9.75 sec  
 At 50% SOC: 10.35 sec  
 Max. Power: 104.3 kW  
 Performance Goal: 13.5 sec at 50% SOC

#### MAXIMUM SPEED @ 50% SOC<sup>1</sup>

At 1/4 Mile: 67.6 mph  
 At 1 Mile: **69.3 mph**  
 Performance Goal: 70 mph in one mile

#### CONSTANT SPEED RANGE @ 45 mph

Range: 60.4 miles  
 Energy Used: 12.99 kWh  
 Average Power: 9.70 kW  
 Efficiency: 215 Wh/mile  
 Specific Energy: 22.2 Wh/kg

#### CONSTANT SPEED RANGE @ 60 mph

Range: 38.8 miles  
 Energy Used: 11.93 kWh  
 Average Power: 18.30 kW  
 Efficiency: 307 Wh/mile  
 Specific Energy: 20.7 Wh/kg

#### DRIVING CYCLE RANGE

Range per SAE J1634: **43.8 miles**  
 Energy Used: 12.81 kWh  
 Average Power: 6.98 kW  
 Efficiency: 292 Wh/mile  
 Specific Energy: 22.3 Wh/kg  
 Performance Goal: 60 miles

#### BRAKING FROM 60 mph

Controlled Dry: 182.2 feet  
 Controlled Wet: 216.3 feet  
 Panic Wet: 192.1 feet  
 Course Deviation: 0.0 feet

#### HANDLING

Avg Time @ 90% SOC: 56.2 sec  
 Avg Time @ 50% SOC: 55.8 sec  
 Avg Time @ 20% SOC: 55.5 sec  
 Avg S-10 ICE Time: 58.3 sec<sup>2</sup>

#### GRADEABILITY (Calculated)

Maximum Speed @ 3%: 68.0 mph  
 Maximum Speed @ 6%: 66.5 mph  
 Maximum Grade: 36.4%  
 Time on 3% Grade: **10 min 3 sec<sup>3</sup>**  
 Performance Goal: 15 Min from 50% SOC

#### CHARGING EFFICIENCY

Efficiency: 470 Wh-AC/mile  
 Energy Cost @ 10¢/kWh: 4.70¢/mile

#### CHARGER

Max Charger Ground Current: <0.01 mA  
 Max Battery Leakage Current: <0.01 mA mA  
 Max DC Charge Current: 16.9 Amps  
 Max AC Charge Current: 19.4 Amps  
 Pwr Factor @ Max Current: 0.97  
 THD(I) @ Max Current: 7.70%  
 Peak Demand: 6.59 kW  
 Time to Recharge: 5 Hrs 15 min  
 Performance Goal: 8 hours

**The Chevrolet S10 Pickup meets the following EV America Minimum Requirements:**

1. The vehicle has a payload of at least 400 pounds.
2. The OEM GVWR has not been increased.
3. The OEM GAWRs have not been increased.
4. Seating capacity is a minimum of 2 passengers.
5. A battery recycling plan has been provided.
6. The OEM passenger space has not been intruded upon by the electrical conversion materials.
7. The vehicle has a parking mechanism or parking brake as required by 49 CFR 571.105.
8. The vehicle has a minimum range between charges of at least 50 miles when loaded with two 166-pound occupants and operated at a constant 45 mph.
9. The vehicle manufacturer has certified that this vehicle complies with the Federal Motor Vehicle Safety Standards (FMVSS) applicable on the date of manufacture.
10. The vehicle manufacturer's proposal states that batteries and/or battery enclosures do not intrude into the passenger compartment during or following a frontal barrier, rear barrier and side impact collision and roll-over.
11. Batteries comply with requirements of SAE J1718, and are so labeled.
12. The vehicle manufacturer has certified concentrations of explosive gases in the battery box do not exceed 25% of the Lower Explosive Limit (LEL) during and following normal or abnormal charging and operation of the vehicle.
13. The battery charger is capable of recharging the main propulsion battery in less than 12 hours when recharging at 208V single phase 40A maximum.
14. The vehicle manufacturer has certified the charger is capable of accepting input voltages of 208 VAC and 240 VAC single phase 60 Hertz, with a tolerance of -13% +6% of rated voltage. Charger input current input current is compatible with 40 amp circuit breakers, and complies with requirements of SAE J1773.
15. The charger has a true power factor of .95 or greater and a harmonic distortion of  $\leq 20\%$  (current at rated load).
16. The charger is fully automatic, determining when "end of charge" conditions are met and transitioning into a mode that maintains the main propulsion battery at a full state of charge while not overcharging when continuously left on charge.
17. Vehicle does not contain exposed conductors, terminals, contact blocks or devices of any type that create the potential for personnel to be exposed to 50 volts or greater.
18. Vehicles are accompanied with manuals for parts, service, operation and maintenance, interconnection wiring diagrams and schematics.
19. The vehicle has a state of charge indicator for the main propulsion batteries.
20. Propulsion power is isolated from the vehicle chassis and battery leakage current from propulsion system to vehicle chassis is less than 0.5 MIU under static conditions.
21. Charging circuits are isolated from the vehicle chassis such that ground currents from a grounded chassis during charging does not exceed 5 mA.
22. Replacement tires are commercially available to the end user.
23. The vehicle has the following interlocks:
  - The controller does not energize in any drive selector position other than "Park" or "Neutral"
  - The start key is removable only in the "Off" position, with the drive selector in "Park"
  - The controller does not initially energize or excite with a preexisting accelerator input.
24. The vehicle manufacturer has certified this vehicle complies with FCC requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, "Unintentional Radiators."
25. The vehicle manufacturer has certified failure of a battery or battery pack is deemed to have occurred if the actual battery capacity is not at least 80% of the nominal ampere hour capacity.
26. The vehicle is equipped with an automatic disconnect and a manual service disconnect for the main propulsion batteries which are clearly labeled.
27. The charging system is compatible with Personnel Protection Systems per SAE J1773.
28. Material Safety Data Sheets (MSDS) for all on-board batteries have been supplied.
29. The level of charge below which the batteries should not be discharged and how the controller automatically limits battery discharge below this level have been identified by the manufacturer.
30. The vehicle manufacturer has verified that the methods(s) of charging the propulsion batteries and the charging algorithm have been reviewed and approved by the battery manufacturer.
31. The charger is capable of meeting the requirements of Section 625 of the National Electric Code (NEC).
32. The vehicle complies with the requirements of 49 CFR 571.301 for fuel-fired heaters.
33. The vehicle has an on-board Battery Energy Management System (BMS).

**This information was prepared with the support of the U.S. Department of Energy (DOE) Award No. DE-FC-07-91ID-13079. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.**

## **4. POMONA LOOP VEHICLE TESTING**

In addition to the Baseline Performance testing, the Field Operations Program also supports Southern California Edison's Pomona Loop testing of electric vehicles. The Pomona Loop testing actually uses two driving loops in the Pomona, California area. One loop is known as the Urban Pomona Loop and it is 19.3 miles long, with elevations ranging from approximately 900 to 1,500 feet above sea level. The Urban Pomona loop has approximately 50 stop signs and traffic lights throughout its route. The second loop is the Freeway Pomona Loop and is 37.2 miles long, with elevations ranging from approximately 700 to 1,150 feet above sea level. The Freeway Pomona Loop's route includes the Orange, San Bernardino, Ontario, and Pomona Freeways (see maps on page 36). While both of these routes do not allow controlled testing to the level that the Baseline Performance testing does, they are good representations of typical California drive cycles. When a vehicle is Pomona Loop tested it is usually subjected to two Urban and two Freeway Pomona Loop tests. This allows the vehicle to be tested both with and without auxiliary vehicle loads on both the Urban and Freeway Pomona Loops. The Pomona Loop test results are available via the Program website. These vehicles include:

- Chevrolet S-10 (nickel-metal-hydride [NiMH])
- Honda EV Plus (NiMH)
- Toyota RAV4 (NiMH)
- Chevrolet S-10 (lead-acid)
- Chrysler Epic (lead-acid)
- General Motors EV1 (lead-acid)
- Ford Ranger (lead-acid).

In addition, Southern California Edison will be performing Pomona Loop testing on five additional vehicles with advanced batteries during 1999.

The following pages contain vehicle fact sheets for vehicles that have been Pomona Loop tested, as well as maps of the two Pomona Loops.

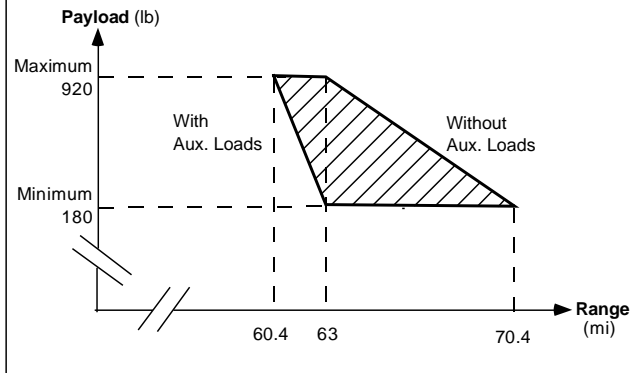
# CHEVROLET S-10 ELECTRIC (NIMH BATTERIES\*) PERFORMANCE CHARACTERIZATION SUMMARY

## ELECTRIC TRANSPORTATION DIVISION



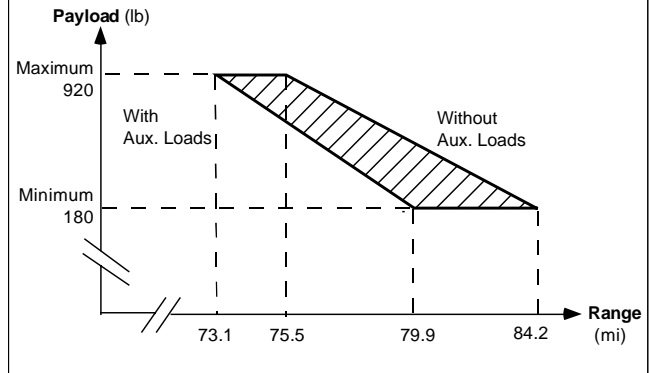
### Urban Range

(On Urban Pomona Loop – see map)



### Freeway Range

(On Freeway Pomona Loop – see map)



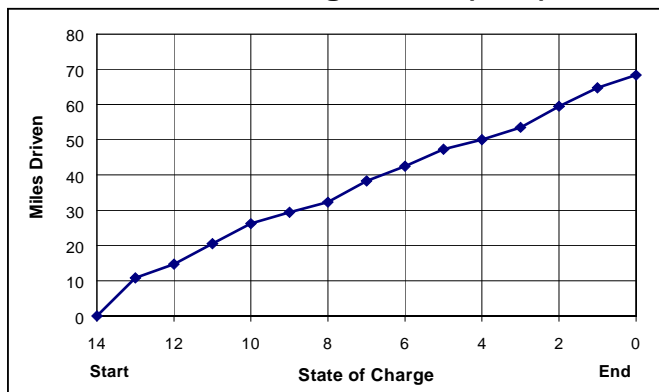
TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	180	180	920	920
AC kWh RECHARGE	54.93	57.09	54.98	51.34
AC kWh/mi.	0.78	0.91	0.87	0.85
RANGE (MI.)	70.4	63.0	63.0	60.4
AVG. AMBIENT TEMP.	63° F	66° F	63° F	50° F

TEST	FW1	FW2	FW3	FW4
Payload (lb.)	180	180	920	920
AC kWh Recharge	56.35	53.29	51.01	57.44
AC kWh/mi.	0.69	0.67	0.68	0.79
RANGE (MI.)	84.2	79.9	75.5	73.1
AVG. AMBIENT TEMP.	68° F	57° F	59° F	55° F

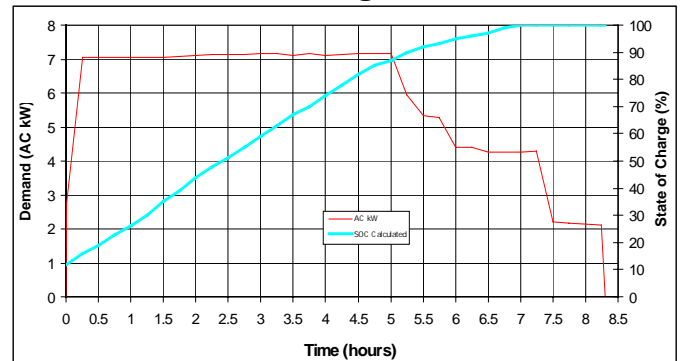
UR1	Urban Range Test, Min Payload, No Auxiliary Loads
UR2	Urban Range Test, Min Payload, A/C on High, Headlights on Low, Radio On
UR3	Urban Range Test, Max Payload, No Auxiliary Loads
UR4	Urban Range Test, Max Payload, A/C on High, Headlights on Low, Radio On

FW1	Freeway Range Test, Min Payload, No Auxiliary Loads
FW2	Freeway Range Test, Min Payload, A/C on High, Headlights on Low, Radio On
FW3	Freeway Range Test, Max Payload, No Auxiliary Loads
FW4	Freeway Range Test, Max Payload, A/C on High, Headlights on Low, Radio On

### State of Charge Meter (UR1)



### Charger



### Measured Value at Peak AC Power

Voltage	233.3 V
Current	30.1 A
Real Power	6.988 kW
Reactive Power	793.8 VAR
Apparent Power	7.038 kVA
Total Power Factor	0.99 PF
Displacement Power Factor	0.99 dPF
Voltage THD	1.0 %
Current THD	3.2 %



# ELECTRIC VEHICLE PERFORMANCE CHARACTERIZATION SUMMARY



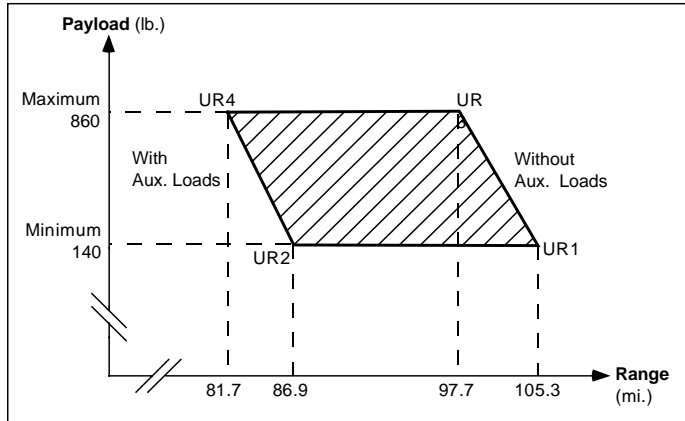
ELECTRIC TRANSPORTATION DIVISION

HONDA EV PLUS  
NIMH BATTERIES

SEPTEMBER 1997

## Urban Range

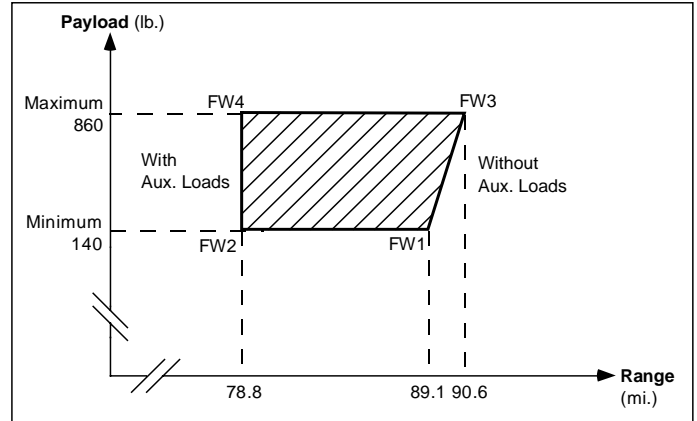
(On Urban Pomona Loop – see other side for map)



Test	UR1	UR2	UR3	UR4
Payload (lb.)	140	140	860	860
AC kWh Recharge	40	43	40	45
AC kWh/mi.	0.38	0.49	0.41	0.55
Range (mi.)	105.3	86.9	97.7	81.7
Avg. Ambient Temp.	79°F	83°F	84°F	89°F

## Freeway Range

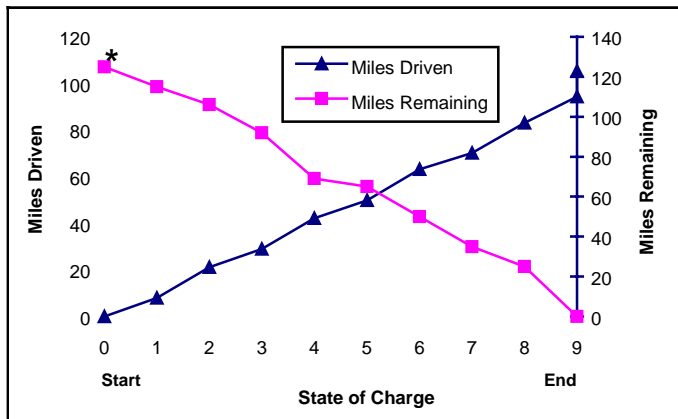
(On Freeway Pomona Loop – see other side for map)



Test	FW1	FW2	FW3	FW4
Payload (lb.)	140	140	860	860
AC kWh Recharge	40	42	44	44
AC kWh/mi.	0.45	0.53	0.49	0.56
Range (mi.)	89.1	78.8	90.6	78.8
Avg. Ambient Temp.	84°F	93°F	93°F	83°F

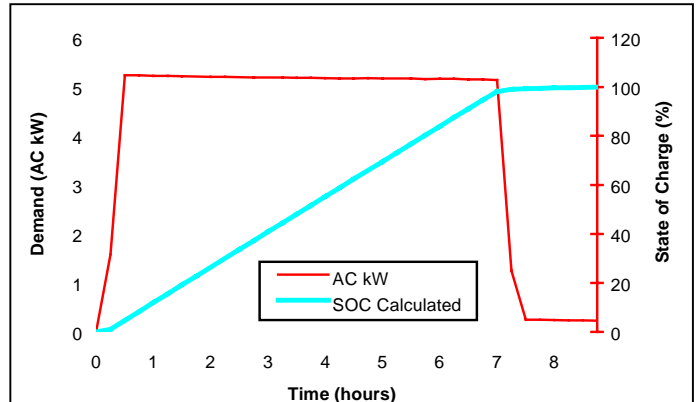
## State of Charge Meter

(Urban Range Test)



\* Initial "Miles Remaining" depend on driving economy before recharge

## Charger



MEASURED VALUE AT PEAK AC POWER	
Voltage	201.3 V
Current	25.78 A
Real Power	5.117 kW
Reactive Power	-584.1 VAR
Apparent Power	5.19 kVA
Total Power Factor	0.99 PF
Displacement Power Factor	0.99 dPF
Voltage THD	0.60%
Current THD	12.10%

# Electric Vehicle Performance Characterization Summary



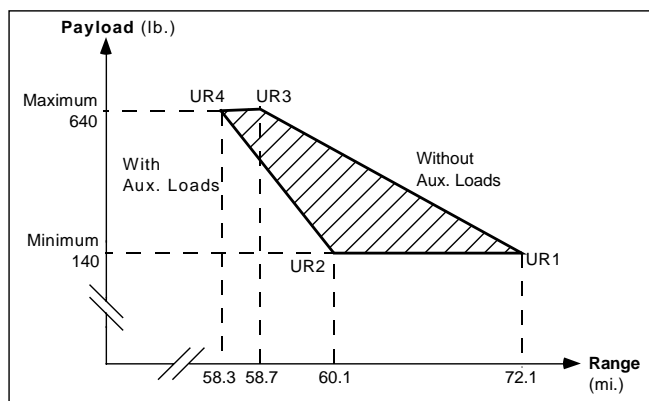
## Electric Transportation Division

### Ford Ranger EV Lead Acid Batteries

March 1998

#### URBAN RANGE

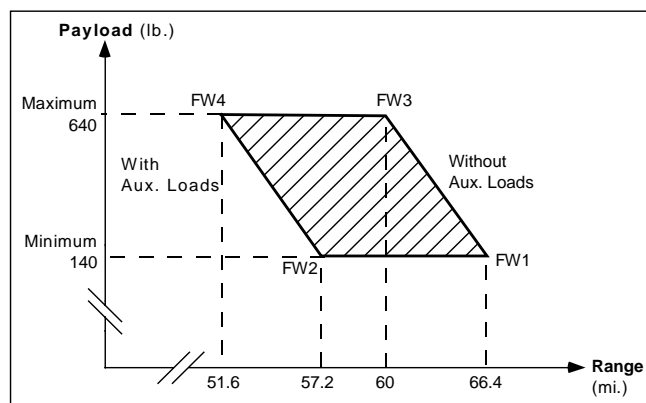
(ON URBAN POMONA LOOP – SEE OTHER SIDE FOR MAP)



TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	140	140	640	640
AC kWh RECHARGE	29.11	28.16	28.20	28.23
AC kWh/MI.	0.40	0.47	0.48	0.48
RANGE (MI.)	72.1	60.1	58.7	58.3
AVG. AMBIENT TEMP.	79°F	61°F	69°F	64°F

#### FREEWAY RANGE

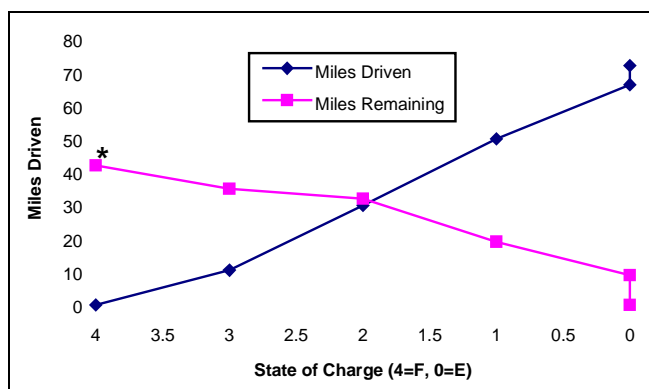
(ON FREEWAY POMONA LOOP – SEE OTHER SIDE FOR MAP)



TEST	FW1	FW2	FW3	FW4
Payload (lb.)	140	140	960	960
AC kWh Recharge	26.31	26.24	25.97	25.62
AC kWh/mi.	0.40	0.46	0.43	0.50
RANGE (MI.)	66.4	57.2	60	51.6
AVG. AMBIENT TEMP.	70°F	64°F	69°F	63°F

#### STATE OF CHARGE METER

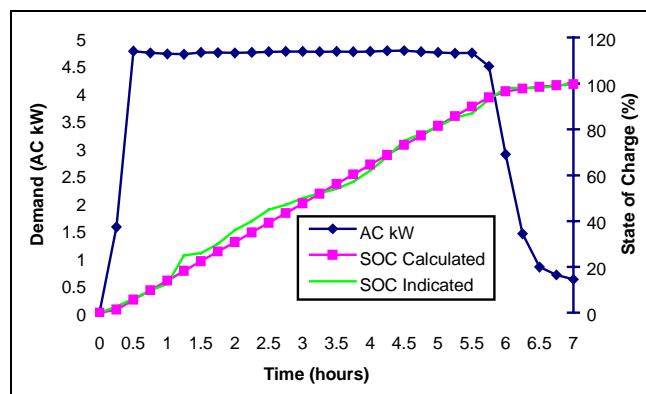
(URBAN RANGE TEST)



\* Initial "Miles Remaining" depend on driving economy before recharge



#### CHARGER



MEASURED VALUE AT PEAK AC POWER	
Voltage	201.4 V
Current	24.22 A
Real Power	4.859 kW
Reactive Power	379.4 VAR
Apparent Power	4.876 kVA
Total Power Factor	1.00 PF
Displacement Power Factor	1.00 dPF
Voltage THD	0.4%
Current THD	2.6%

# ELECTRIC VEHICLE PERFORMANCE CHARACTERIZATION SUMMARY

ELECTRIC TRANSPORTATION DIVISION

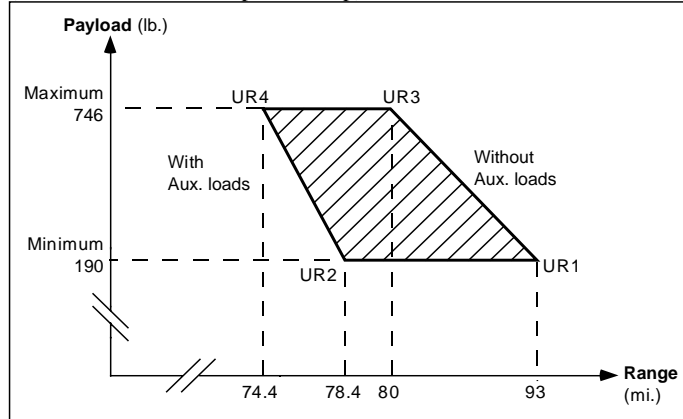


An EDISON INTERNATIONAL Company

## TOYOTA RAV4 NiMH BATTERIES FEBRUARY 1998

### Urban Range

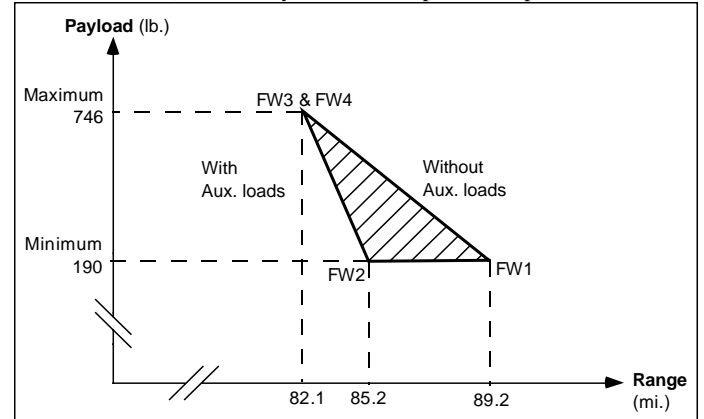
(On Urban Pomona Loop – see map)



TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	190	190	746	746
AC kWh RECHARGE	31.56	30.73	32.31	33.38
AC kWh/MI.	0.34	0.39	0.40	0.45
RANGE (MI.)	93	78.4	80	74.4
AVG. AMBIENT TEMP.	54° F	59° F	57° F	58° F

### Freeway Range

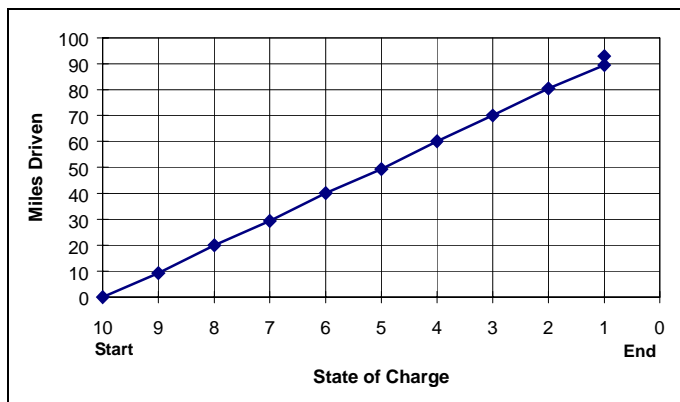
(On Freeway Pomona Loop – see map)



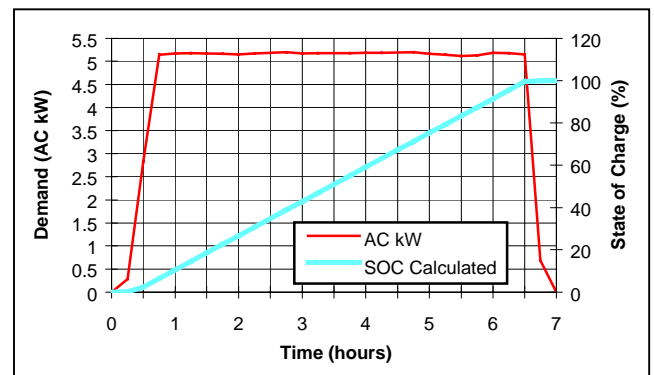
TEST	FW1	FW2	FW3	FW4
PAYLOAD (LB.)	190	190	746	746
AC kWh RECHARGE	31.44	31.14	33.2	34.49
AC kWh/MI.	0.35	0.37	0.40	0.42
RANGE (MI.)	89.2	85.2	82.1	82.1
AVG. AMBIENT TEMP.	59° F	64° F	62° F	63° F

### State of Charge Meter

(Urban Range Test)



### Charger



### Measured Value at Peak AC Power

Voltage	207.8 V
Current	24.63 A
Real Power	5.066 kW
Reactive Power	705.6 VAR
Apparent Power	5.117 kVA
Total Power Factor	0.99 PF
Displacement Power Factor	0.99 dPF
Voltage THD	0.5%
Current THD	2.2%

# ELECTRIC VEHICLE PERFORMANCE CHARACTERIZATION SUMMARY

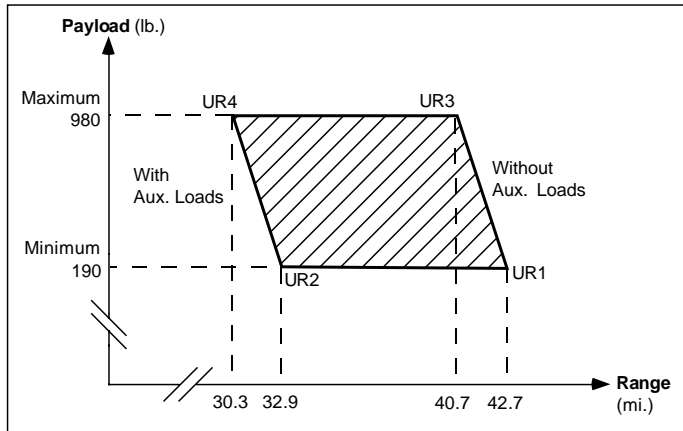


ELECTRIC TRANSPORTATION DIVISION

## CHEVROLET S-10 ELECTRIC LEAD ACID BATTERIES SEPTEMBER 1997

### Urban Range

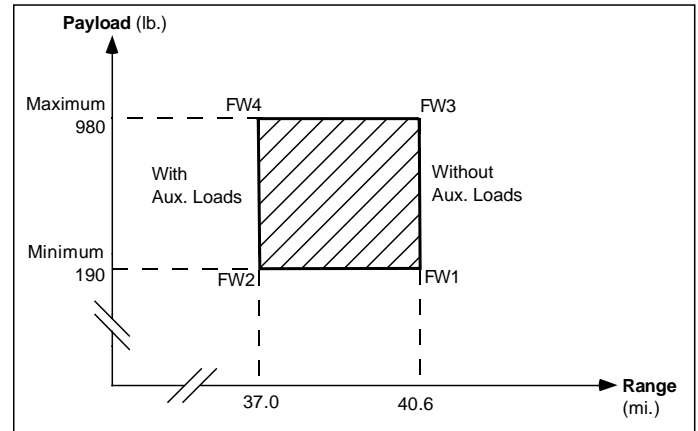
(On Urban Pomona Loop – see map)



TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	190	190	980	980
AC kWh RECHARGE	16.93	17.59	19.21	20.24
AC kWh/MI.	0.396	0.535	0.472	0.668
RANGE (MI.)	42.7	32.9	40.7	30.3
AVG. AMBIENT TEMP.	77° F	91° F	89° F	90° F

### Freeway Range

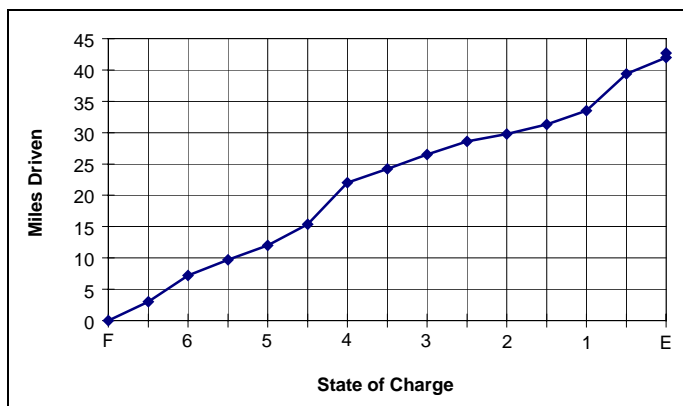
(On Freeway Pomona Loop – see map)



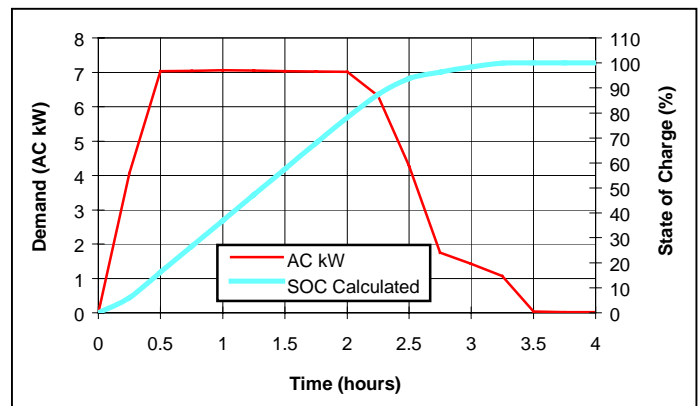
TEST	FW1	FW2	FW3	FW4
PAYLOAD (lb.)	190	190	980	980
AC kWh Recharge	19.29	15.80	16.38	16.02
AC kWh/mi.	0.475	0.427	0.403	0.433
RANGE (MI.)	40.6	37.0	40.6	37.0
AVG. AMBIENT TEMP.	92° F	87° F	83° F	82° F

### State of Charge Meter

(Urban Range Test)



### Charger



Measured Value at Peak AC Power	
Voltage	232.3 V
Current	21.71 A
Real Power	5.013 kW
Reactive Power	-481.7 VAR
Apparent Power	5.045 kVA
Total Power Factor	0.99 PF
Displacement Power Factor	1.00 dPF
Voltage THD	0.4%
Current THD	4.8%

# ELECTRIC VEHICLE PERFORMANCE CHARACTERIZATION SUMMARY

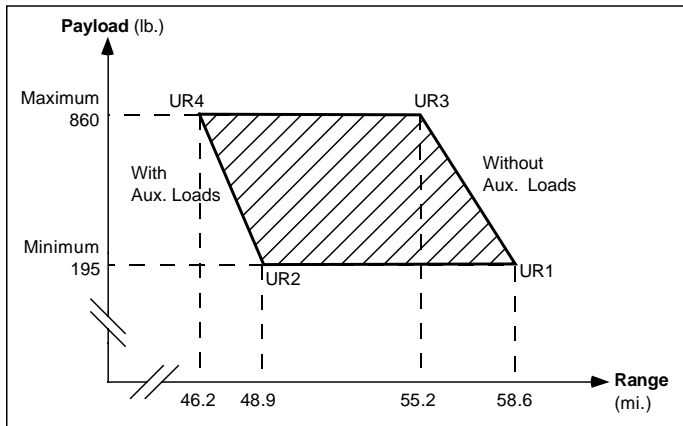


ELECTRIC TRANSPORTATION DIVISION

## CHRYSLER EPIC LEAD ACID BATTERIES JUNE 1997

### Urban Range

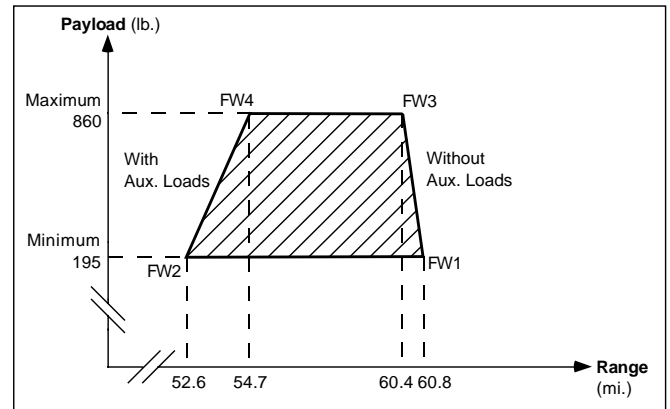
(On Urban Pomona Loop – see map)



TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	195	195	860	860
AC kWh RECHARGE	34.45	33.80	35.47	33.11
AC kWh/mi.	0.59	0.69	0.64	0.72
RANGE (MI.)	58.6	48.9	55.2	46.2
AVG. AMBIENT TEMP.	75° F	73° F	72° F	71° F

### Freeway Range

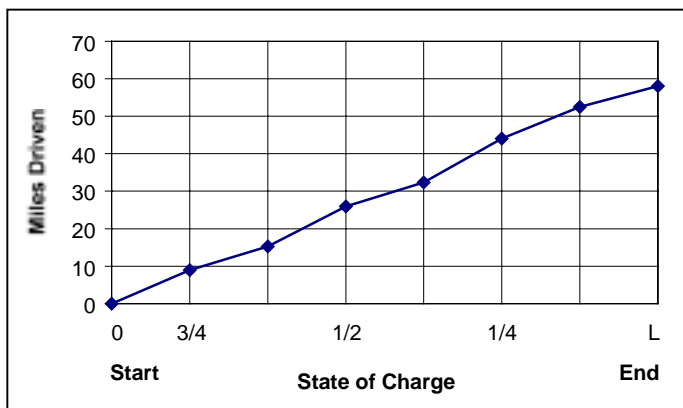
(On Freeway Pomona Loop – see map)



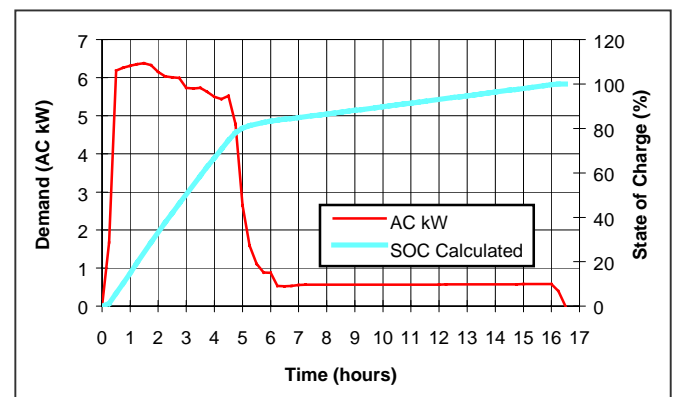
TEST	FW1	FW2	FW3	FW4
PAYLOAD (lb.)	195	195	860	860
AC kWh Recharge	31.43	32.56	33.35	35.39
AC kWh/mi.	0.52	0.62	0.55	0.65
RANGE (MI.)	60.8	52.6	60.4	54.7
AVG. AMBIENT TEMP.	81° F	83° F	79° F	77° F

### State of Charge Meter

(Urban Range Test)



### Charger



Measured Value at Peak AC Power	
Voltage	202.6
Current	30.54 A
Real Power	6.159 kW
Reactive Power	-424.2 VAR
Apparent Power	6.190 kVA
Total Power Factor	1.00 PF
Displacement Power Factor	1.00 dPF
Voltage THD	0.5%
Current THD	6.1%

# ELECTRIC VEHICLE PERFORMANCE CHARACTERIZATION SUMMARY

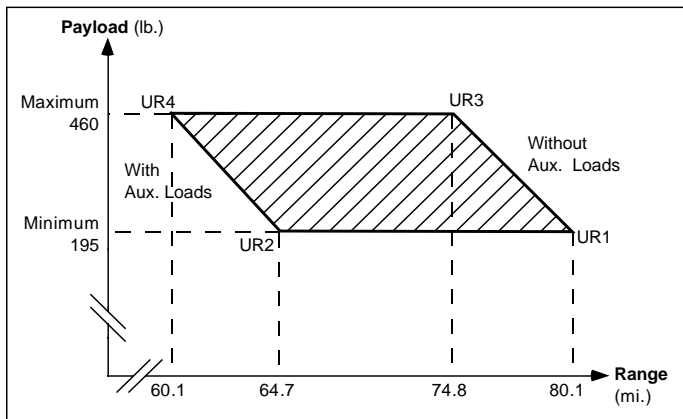


ELECTRIC TRANSPORTATION DIVISION

## GM EV1 LEAD ACID BATTERIES SEPTEMBER 1997

### Urban Range

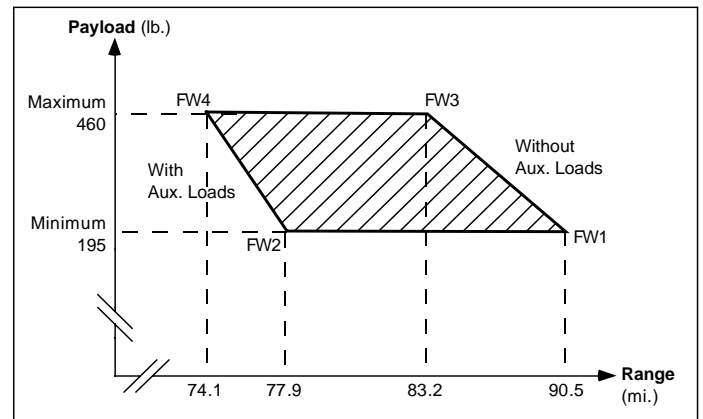
(On Urban Pomona Loop – see map)



TEST	UR1	UR2	UR3	UR4
PAYLOAD (LB.)	195	195	460	460
AC kWh RECHARGE	22.50	19.36	18.34	18.28
AC kWh/MI.	0.281	0.299	0.245	0.304
RANGE (MI.)	80.1	64.7	74.8	60.1
AVG. AMBIENT TEMP.	79° F	76° F	73° F	78° F

### Freeway Range

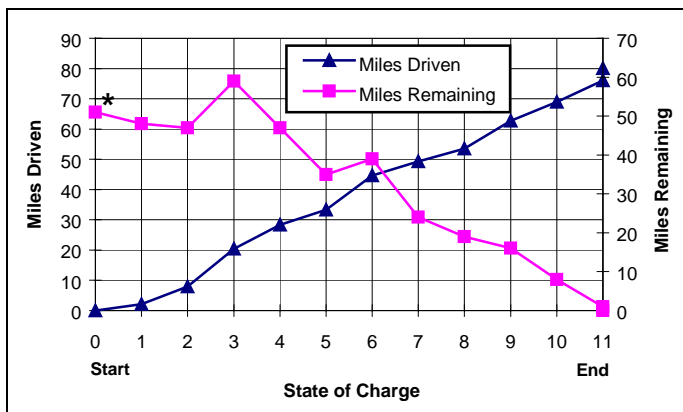
(On Freeway Pomona Loop – see map)



TEST	FW1	FW2	FW3	FW4
PAYLOAD (lb.)	195	195	460	460
AC kWh Recharge	21.68	18.12	20.73	21.57
AC kWh/mi.	0.240	0.233	0.25	0.291
RANGE (MI.)	90.5	77.9	83.2	74.1
AVG. AMBIENT TEMP.	80° F	91° F	82° F	82° F

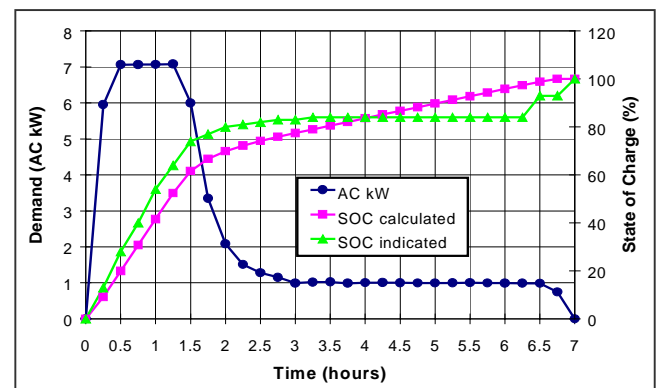
### State of Charge Meter

(Urban Range Test)



\* Initial "Miles Remaining" depend on driving economy before recharge

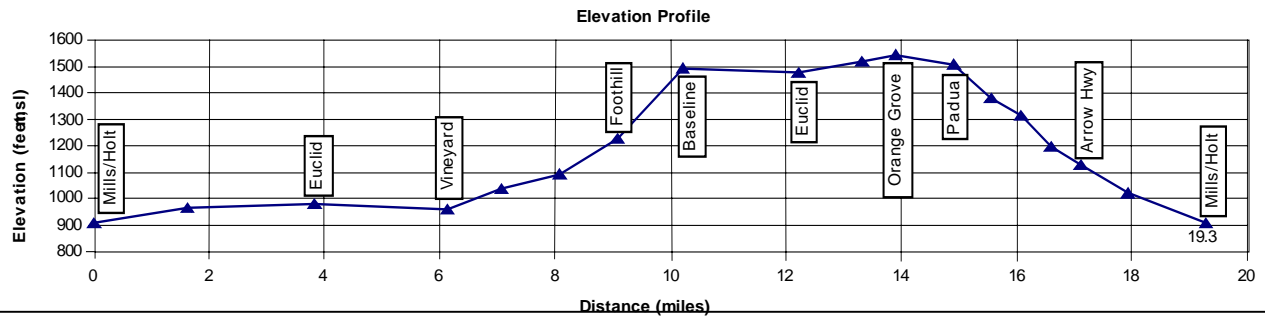
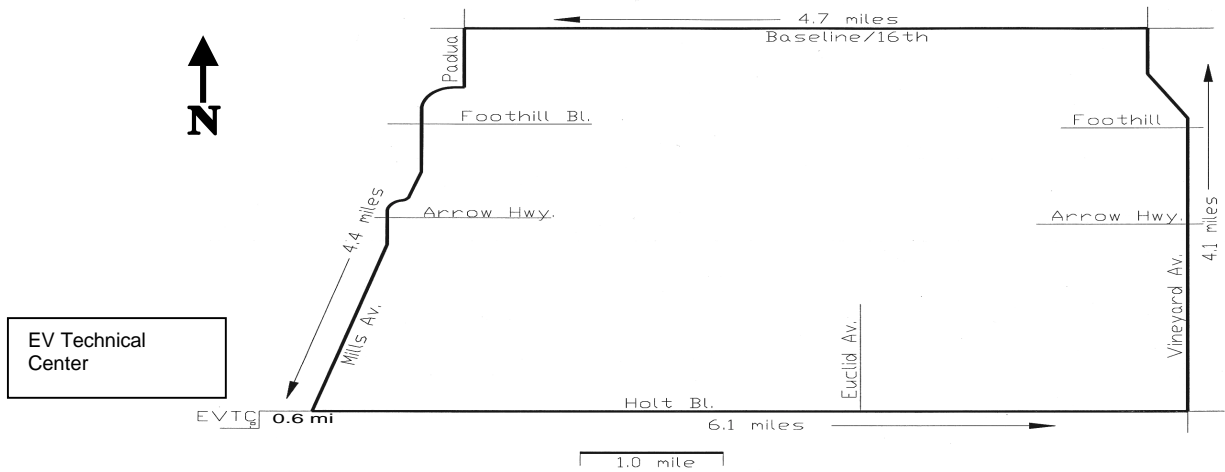
### Charger



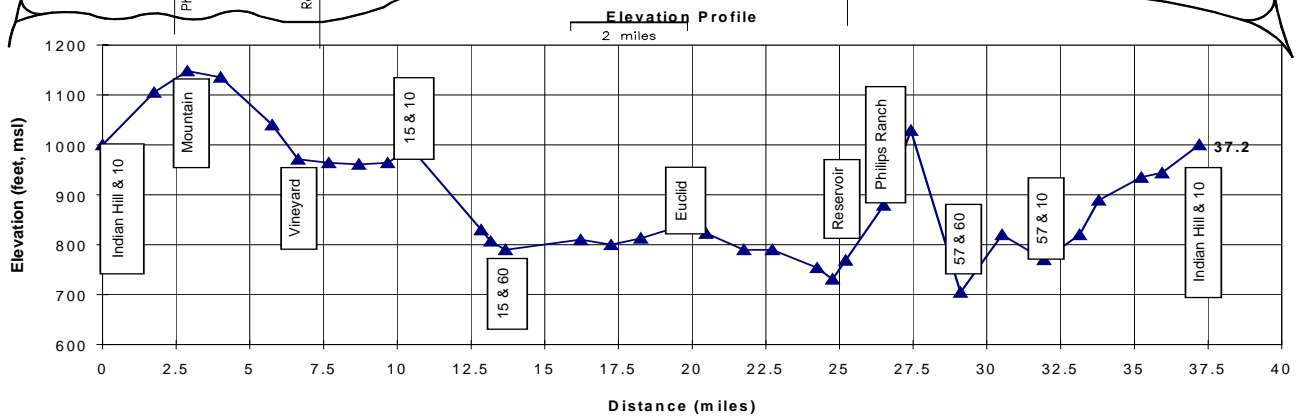
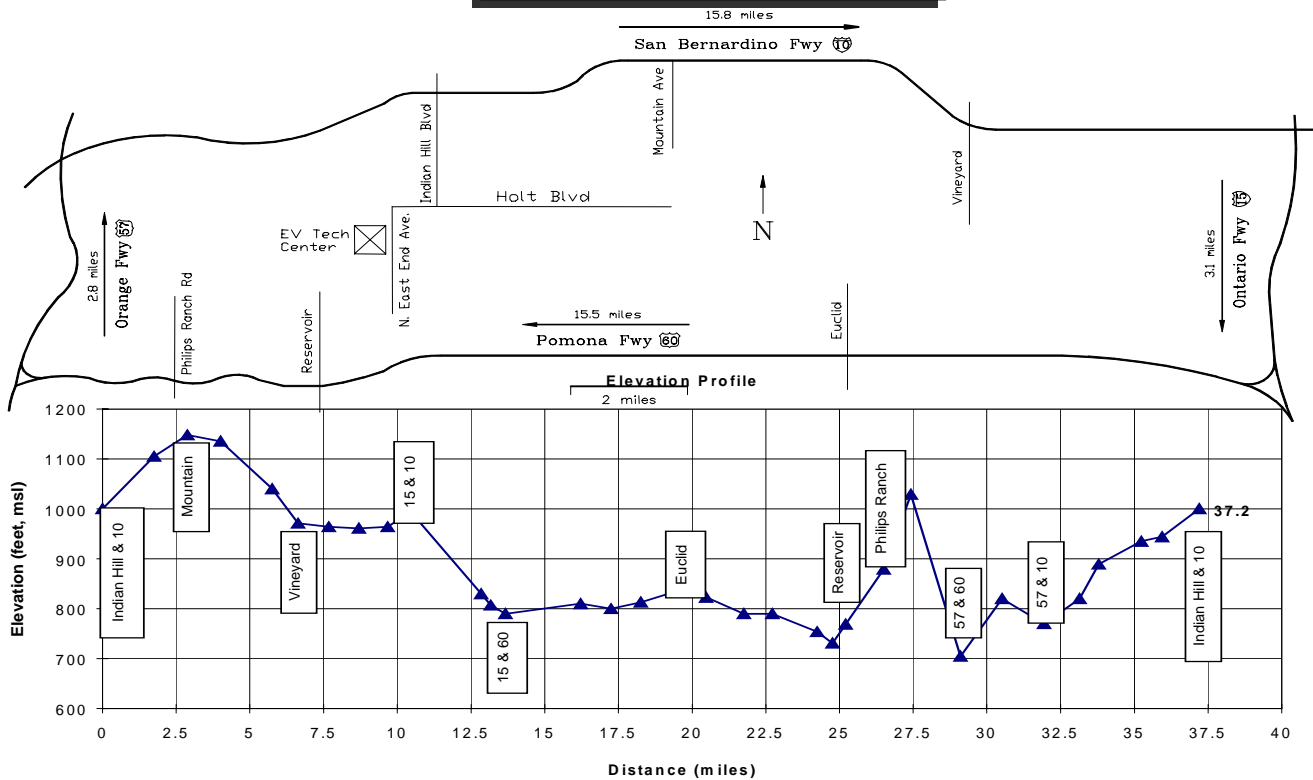
Measured Value at Peak AC Power	
Voltage	233.5 V
Current	30.29 A
Real Power	7.019 kW
Reactive Power	840.3 VAR
Apparent Power	7.074 kVA
Total Power Factor	0.99 PF
Displacement Power Factor	0.99 dPF
Voltage THD	0.3%
Current THD	3.4%



## URBAN POMONA LOOP



## FREEWAY POMONA LOOP



## **5. ACCELERATED RELIABILITY VEHICLE TESTING**

Accelerated Reliability vehicle testing is similar to Fleet Operations testing except that the vehicles are operated in an accelerated mileage mode. The goal is to obtain several years of traditional fleet use operations data within a single year, up to 25,000 miles. The Program has recently completed Accelerated Reliability testing of several Chevrolet S-10 pickups and one Chrysler EPIC minivan. Both models were equipped with lead-acid batteries.

The testing of both the S-10 and Chrysler identified some problems, primarily with batteries. The original Delphi batteries in the S-10s are no longer being used. Instead, Chevrolet is using Panasonic lead-acid batteries except in California, where the GM Ovonic NiMH battery is being used. Similarly, Chrysler has also gone to a NiMH battery, which is manufactured by SAFT. These issues will be more closely examined in future vehicle reports, which should be available this summer on the Program's website.

Additionally, several Ford Rangers (lead-acid and NiMH batteries) and Toyota RAV4s (NiMH) are currently being Accelerated Reliability tested. The Ford Ranger tests will incorporate fast (Level 3) charging when this option becomes available later this year.

## **6. FLEET VEHICLE TESTING**

In the Fleet Operations testing method, QVTs collect data on electric vehicles within their fleets. QVT personnel use the vehicles in typical utility missions such as meter reading.

The data collected includes total energy use (kWh), cumulative and period energy use per mile, cumulative and period mileage, number of hours on charge, energy use during both on- and off-peak hours, the number of charging events per period, vehicle inventories, cumulative mileage, and 24-hour charging profiles. The data is disseminated not only for entire fleets, but also for single model types and individual vehicles. These results are available via the Program's website. The Program has Chevrolet S-10s, Ford Rangers, and Toyota RAV4s under contract with the QVTs for Fleet testing. This information is also provided for the vehicles in Accelerated Reliability testing. In addition, Southern California Edison voluntarily provides this data on several other vehicles within their fleet, including the following vehicle models:

- GM EV1
- Honda EV Plus
- Nissan Altra EV
- Solectria Coupe, E10 and Force
- Conceptor G-Van
- Specialty Shuttle
- US Electricar S-10
- Ford Ranger
- Chevrolet S-10
- Chrysler EPIC.

## **7. NATIONAL LOANER PROGRAM**

The National Loaner Program makes electric vehicles available to federal fleets on a trial basis. This allows the federal fleets to test-drive the electric vehicles, usually for 1- or 2-month periods. This program is being conducted in partnership with six electric utilities around the country. These are listed here with points of contact:

- Virginia Power (Greg Frahm, 804-257-4005)
- Southern California Edison (Cecilia Mushinskie, 626-302-3934)
- San Diego Gas and Electric (Risa Baron, 619-654-1103)
- Potomac Electric Power Company (Bonnie Graziano, 202-872-2973)
- Georgia Power (Polly Prater, 404-506-4640)
- Boston Edison. (Davids Dilts, 617-424-3590)

Each utility loans from three to ten vehicles to the federal fleets within each utility's service territory. The utilities procure and maintain the vehicles; identify, contact, and coordinate with the federal fleets for the temporary placement of the loaner vehicles; and provide temporary charging infrastructure. The utilities have also committed to supporting the federal fleets if they decide to lease an electric vehicle by helping to install permanent charging infrastructure, helping the federal fleets decide which electric vehicle is the "right" vehicle for the federal fleet's mission needs, supporting the leasing process, and providing assistance with any maintenance problems.

The Field Operations Program is managing DOE's National Loaner Program, and the current National Loaner Program contracts run through calendar year 2000. If a federal fleet decides to lease an electric vehicle, it can then take advantage of the incremental funding program offered by DOE.

## 8. INCREMENTAL FUNDING PROGRAM

To encourage and support the leasing of electric vehicles by federal fleets, DOE is providing funding to buy-down the incremental costs of electric vehicles. DOE will pay 50% of the incremental costs when a federal agency leases an electric vehicle. The incremental funding is being conducted as part of the Field Operations Program.

The incremental cost is the difference between the General Services Administration's cost to lease a gasoline-powered vehicle and the additional cost to lease an electric version of the same vehicle. For example, the General Services Administration's lease rate, including estimated mileage fees, for a gasoline-powered small pickup is approximately \$220 per month, while an electric Ford Ranger with lead-acid batteries can be leased for \$349 per month. The difference, or incremental cost, is \$129 per month. The Field Operations Program pays half of this amount, or \$64.50.

Ford is leasing lead-acid equipped Rangers in all states except California. There, Ford is leasing Rangers equipped with NiMH batteries, and this vehicle is leasing for \$450 per month. Another vehicle available in California with NiMH batteries is the Chrysler EPIC minivan. The EPIC is also leasing for \$450 per month.

General Motors is also offering a NiMH-equipped version of its Chevrolet S-10 in California for \$440 per month. The lead-acid equipped S-10 is available nationally. All of the NiMH-equipped electric vehicles have 3-year, 36,000 mile warranties and the lease periods are for 3 years. Toyota and Honda are also leasing electric vehicles in California with NiMH batteries.

The Incremental Funding Program has been popular with various federal agencies. During the first three months of 1999, over 30 federal agencies or divisions have requested information from the Field Operations Program. Some of the information requested has included help in identifying available electric vehicles that fit the agency's mission requirements, whether to lease or purchase an electric vehicle, how to lease an electric vehicle, and identifying vehicle manufacturer contacts. Program support has included talks to agency personnel and Clean City members. To date, it is estimated that these 30 agencies and divisions will order 160 electric vehicles with incremental funding support from DOE. Some of the 30 agencies include

- Lawrence Livermore National Laboratory
- Sandia National Laboratory
- Los Alamos National Laboratory
- Lawrence Berkeley National Laboratory
- Environmental Protection Agency - Seattle and Kansas City
- DOE Headquarters
- Bonneville Power Administration
- Department Of Agriculture
- General Services Administration
- DOE Oakland Field Office
- Tennessee Valley Authority
- Department of Transportation
- National Park Service - Grand Canyon
- National Park Service – Rock Creek Park

- National Park Service - Patuxent Wildlife Refuge
- Smithsonian Institution
- Bureau of Reclamation - Colorado
- Forest Service – Portland
- Architect of the Capitol
- U.S. Navy – Charleston
- U.S. Navy – San Diego
- U.S. Marines - California
- NASA - California
- U.S. Air Force -Washington and California.

DOE Incremental Funding contacts at the INEEL are:

Jim Francfort	Alison Conner
208-526-6787	208-526-7799
francfje@inel.gov	amf@inel.gov

## 9. PROGRAM FOLDER

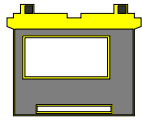
The Field Operations Program has developed a Program Folder for disseminating general electric vehicle information as well as testing results. Approximately 750 Folders have been disseminated via venues that include national conferences, the Alternative Fuel Hotline, phone requests to the INEEL, and the Program's website. The Folder contents include Baseline Performance fact sheets for individual vehicles, Pomona Loop testing fact sheets, discussion of electric vehicle testing trends and several general information sheets about electric vehicle components. These general areas include:

- Electric vehicle batteries
- History of electric vehicles
- Electric vehicle charging information
- Electric vehicle auxiliary equipment information
- Electric vehicle and gasoline vehicle comparison
- Electric vehicle motor and controller information.

Examples of the information included in the Folder are the inserts "Electric Vehicle Batteries" and "History of Electric Vehicles," which are included on the following pages. Baseline Performance and Pomona Loop fact sheets, examples of which are in Chapters 3 and 4, are also included. The comments and feedback received about the Program Folder have been very favorable. The only negative comment has been that we (DOE) should have done something like the Folder previously. The Folder is targeted to the Fleet Manager or member of the general public who is searching for realistic electric vehicle information without the "hype" so often provided.

Program folders can be requested via the Programs website at <http://ev.inel.gov/sop>, or from Jim Francfort at francfje@inel.gov.

# EV Batteries



The electric vehicle battery pack performs the same function as the gasoline tank in a conventional vehicle: it stores the energy needed to operate the vehicle. Battery packs usually contain 10 to 52 individual 6-, 8-, or 12-volt batteries similar to the starter battery used in gasoline vehicles. While a gasoline tank can store the energy to drive 300 to 500 miles before refilling, the current generation of batteries will only store enough energy to drive 50 to 150 miles between recharging.

The range of an electric vehicle (the distance traveled between recharging) depends on the energy stored in the battery pack. Just as the amount of gasoline can be increased by installing a larger gas tank, the amount of stored electrical energy can also be increased by increasing the number and/or size of batteries in the battery pack. However, when batteries are added, the weight is increased and the space used by the battery pack increases. Because of this weight and space penalty, there is a limit to the number of batteries that can be used for any given vehicle.

To increase the range and improve the performance of electric vehicles, batteries are being developed that can store larger amounts of energy with the same weight and volume. The United States Advanced Battery Consortium (USABC) was established to develop the next generation electric vehicle batteries. The members of the USABC include the big three U.S. automobile manufacturers, the Electric Power Research Institute, battery manufacturers, and the United States Department of Energy (DOE).

The performance goals for these batteries are as follows:

<b>USABC Battery Performance Goals</b>				
	Energy Density Whr/kg	Power Density (W/kg)	Life Cycles per battery	Cost (\$)
Current Lead-acid	35	150	500	150
USABC mid-term goals	80	150	600	250
USABC long-term goals	200	400	1,000	<100
Impact on Vehicle Performance	Range	Acceleration	Life cycle cost; Replacement period	Acquisition cost; Battery replacement cost

When these long-term goals are met, batteries will be available to provide electric vehicles with ranges greater than 200 miles and a battery life greater than 100,000 miles.

Battery systems being supported by the USABC to meet the midterm goals include nickel-metal-hydride (NiMH) battery technologies. The USABC is also supporting battery systems to meet the long-

term goals. The two systems being investigated are the lithium polymer and the lithium-ion battery systems.

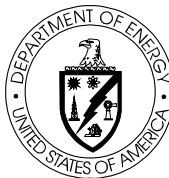
Independent of the battery development efforts supported by the USABC, the Advanced Lead-acid Battery Association, an association of lead-acid battery manufacturers, is supporting development programs to improve the near-term performance of the lead-acid battery.

<b>Performance of Advanced EV Battery Systems</b>			
	Energy Density (Whr/kg)	Power Density (W/kg)	Life Cycles per battery
Advanced Lead-acid	48	150	800
GM Ovonic NiMH	70	220	>600
SAFT NiMH	70	150	1500
SAFT lithium ion	120	230	600
Lithium polymer	150	350	<600
Zebra sodium-nickel chloride	86	150	<1000

For further information, please contact:

U.S. Department of Energy  
DOE Field Operations Program  
Website: <http://ev.inel.gov/sop>

National Alternative Fuels Hotline  
(800) 423-1DOE  
<http://www.afdc.doe.gov>



**NOTE:** The information for the tables "USABC Battery Performance Goals" and "Performance of Advanced EV Battery Systems" was obtained from the *Second EPRI Battery and Charging Issues Workshop: Proceedings and Presentation Material* Final Report, February 1998. The workshop was sponsored by the Electric Power Research Institute. Speakers included representatives from battery and automotive manufacturers, and DOE. Battery performance information is compiled from several speaker's slides, and as such, the reader must recognize that different assumptions and testing methods are used to determine battery performance characteristics. This information should only be considered as estimates of technology performance. In addition, the USABC performance goals are not definitive statements of future performance.

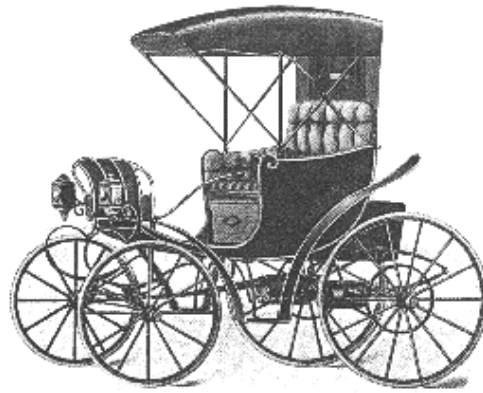
# History of Electric Vehicles

## The Early Years (1890 - 1930)

The electric vehicle is not a recent development. In fact, the electric vehicle has been around for over 100 years, and it has an interesting history of development that continues to the present.

France and England were the first nations to develop the electric vehicle in the late 1800s. It was not until 1895 that Americans began to devote attention to electric vehicles. Many innovations followed and interest in motor vehicles increased greatly in the late 1890s and early 1900s. In 1897 the first commercial application was established as a fleet of New York City taxis.

The early electric vehicles, such as the 1902 Wood's Phaeton, were little more than electrified horseless carriages and surreys. The Phaeton had a range of 18 miles, a top speed of 14 mph and cost \$2,000.



**1902 Wood's Electric Phaeton**

By the turn of the century, America was prosperous and the motor vehicle, now available in steam, electric, or gasoline versions, was becoming more popular. The years 1899 and 1900 were the high point of electric vehicles in America, as they outsold all other types of cars. Electric vehicles had many advantages over their competitors in the early 1900s. They did not have the vibration, smell, and noise associated with gasoline cars. Changing gears on gasoline cars was the most difficult part of driving, while electric vehicles did not require gear changes. While steam-powered cars also had no gear shifting, they suffered from long start-up times of up to 45 minutes on cold mornings. The steam cars had less range before needing water than an electric's range on a single charge. The only good roads of the period were in town, causing most travel to be local commuting, a perfect situation for electric vehicles, since their range was limited. The electric vehicle was the preferred choice of many because it did not require the manual effort to start, as with the hand crank on gasoline vehicles, and there was no wrestling with a gear shifter.



**New York City Electric Taxis**

While basic electric cars cost under \$1,000, most early electric vehicles were ornate, massive carriages designed for the upper class. They had fancy interiors, with expensive materials, and averaged \$3,000 by 1910. Electric vehicles enjoyed success into the 1920s with production peaking in 1912.

The decline of the electric vehicle was brought about by several major developments:

1. By the 1920s, America had a better system of roads that now connected cities, bringing with it the need for longer-range vehicles.
2. The discovery of Texas crude oil reduced the price of gasoline so that it was affordable to the average consumer.
3. The invention of the electric starter by Charles Kettering in 1912 eliminated the need for the hand crank.
4. The initiation of mass production of internal combustion engine vehicles by Henry Ford made these vehicles widely available and affordable in the \$500 to \$1,000 price range. By contrast, the price of the less efficiently produced electric vehicles continued to rise. In 1912, an electric roadster sold for \$1,750, while a gasoline car sold for \$650.



**1918 Detroit**

## **The Middle Years (1930 - 1990)**

Electric vehicles had all but disappeared by 1935. The years following until the 1960s were dead years for electric vehicle development and for use as personal transportation.

The 1960s and 1970s saw a need for alternative fueled vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil. Many attempts to produce practical electric vehicles occurred during the years from 1960 to the present.

In the early 1960s, the Boyertown Auto Body Works jointly formed the Battronic Truck Company with Smith Delivery Vehicles, Ltd., of England and the Exide Division of the Electric Battery Company. The first Battronic electric truck was delivered to the Potomac Edison Company in 1964. This truck was capable of speeds of 25 mph, a range of 62 miles and a payload of 2,500 pounds.



**1971 Battronic Truck**

Battronic worked with General Electric from 1973 to 1983 to produce 175 utility vans for use in the utility industry and to demonstrate the capabilities of battery powered vehicles. Battronic also developed and produced about 20 passenger buses in the mid 1970s.

Two companies were leaders in electric car production during this time. Sebring-Vanguard produced over 2,000 “CitiCars.” These cars had a top speed of 44 mph, a normal cruise speed of 38 mph and a range of 50 to 60 miles.

The other company was Elcar Corporation which produced the “Elcar”. The Elcar had a top speed of 45 mph, a range of 60 miles and cost between \$4,000 and \$4,500.



**Sebring -Vanguard CitiCar**



**Elcar**

In 1975 the United States Postal Service purchased 350 electric delivery jeeps from the American Motor Company to be used in a test program. These jeeps had a top speed of 50 mph and a range of 40 miles at a speed of 40 mph. Heating and defrosting were accomplished with a gas heater and the recharge time was 10 hours.



**1975 Electric Postal Vehicle**

## **The Current Years (1990 to Present)**

Several legislative and regulatory actions have renewed electric vehicle development efforts. Primary among these is the 1990 Clean Air Act Amendment, the 1992 Energy Policy Act, and regulations issued by the California Air Resources Board (CARB). In addition to more stringent air emissions requirements and regulations requiring reductions in gasoline use, several states have issued Zero Emission Vehicle requirements.

The “Big Three” automobile manufacturers, and the Department of Energy, as well as a number of vehicle conversion companies are actively involved in electric vehicle development through the Partnership for a New Generation of Vehicles (PNGV). Electric conversions of familiar gasoline powered vehicles, as well as electric vehicles designed from the ground up, are

now available that reach super highway speeds with ranges of 50 to 150 miles between recharging.

Some examples of these vehicles are the Chevrolet S-10 pickup truck, converted by US Electricar and no longer available. It was powered by dual alternating current motors and lead-acid batteries. It had a range of about 60 miles, and could be recharged in less than 7 hours.



**US Electricar S-10 Electric Pick Up Truck**

The Geo Metro, converted by Solectria Corp., is an electric-powered 4-passenger sedan powered by an alternating current motor and lead-acid batteries. It has a range of 50 miles, and it can be recharged in less than 8 hours. During the 1994 American Tour de Sol from New York City to Philadelphia, a 1994 Solectria Geo Metro cruised over 200 miles on a single charge using Ovonic NiMH batteries.

The “Big Three” automobile manufacturers are also developing electric vehicles. An early 1990s vehicle was the Ford Ecostar utility van with an alternating current motor and sodium sulfur batteries. The top speed was 70 mph and it had a range of 80 to 100 miles. While about 100 Ecostars were produced, it was considered an R&D vehicle and never offered commercially.



**Ford Ecostar**

Ford is now offering an electric version of its Ford Ranger pickup. It has a range of about 65 miles with its lead-acid batteries, has a top speed of 75 mph, it accelerates from 0 to 50 mph in 12 seconds, and it has a payload of 700 pounds.



**Ford Ranger Pickup**

General Motors has designed and developed an electric car from the ground up instead of modifying an existing vehicle. This vehicle, called the EV1, is a 2-passenger sports car powered by a liquid-cooled alternating current motor and lead-acid batteries. The EV1 has a top speed of 80 mph, has a range of 80 miles, and can accelerate from 0 to 50 mph in less than 7 seconds.



**GM EV1**

In addition to the EV1, General Motors is offering an electric vehicle Chevrolet S-10 pickup. This vehicle has a range of 45 miles, it accelerates from 0 to 50 mph in 10 seconds, and it has a payload of 950 pounds.

Other electric vehicles that are now available in some states, or will be available during 1998, include the Toyota RAV4 sport utility, the Honda EV Plus sedan, and the Chrysler EPIC minivan. These three vehicles are all equipped with advanced NiMH battery packs. Nissan has announced that they will place limited numbers of their Altra EV station wagons in California fleets during 1998. The Altra is equipped with a lithium-ion battery pack. In addition, both Ford and General Motors have announced that during 1998 the Ranger, the EV1, and the S-10 pickup will all be available with NiMH battery packs.



**Toyota RAV4**

While the vehicles currently available will satisfy the driving requirements of many fleet operators and two car families, the cost of \$30,000 to \$40,000 makes them expensive. However, this cost can be considerably lower when tax credits and incentives are included.

Large-volume production and improvements in the production process are expected to reduce this price to the range of current gasoline-powered vehicles.

For further information, please  
contact:

U.S. Department of Energy  
DOE Field Operations Program  
Website: <http://ev.inel.gov/sop>

National Alternative Fuels Hotline  
(800) 423-1DOE  
<http://www.afdc.doe.gov>



## **10. FEDERAL AGENCY SUPPORT**

The Field Operations Program personnel and other INEEL personnel have responded to inquiries from other federal agencies for electric vehicle technical support. These inquiring agencies have included the Grand Canyon National Park, which received support in determining how to optimize the performance of their electric bus fleet; Yellowstone National Park, which is attempting to determine the feasibility of incorporating electric vehicles into their fleet; Hanging Rope National Monument, which requested support with their battery backup system at a marina on the Colorado River; and the Utah Olympic Committee, which is considering using electric shuttles during the 2002 Winter Olympics. The Program is also providing technical and testing support to the U.S. Postal Service in conjunction with their procurement of up to 6,000 light-duty long-life electric delivery vehicles. Some of the federal agencies have requested technical support to help them determine if they should lease electric vehicles in conjunction with the DOE Incremental Funding Program. These include:

- Environmental Protection Agency
- Bonneville Power Administration
- General Services Administration
- Tennessee Valley Authority
- National Park Service
- Department of Interior
- Bureau of Reclamation
- Forest Service
- NASA.

## 11. OTHER PROGRAM ACTIVITIES

**Infrastructure Working Council.** Through the Field Operations Program, DOE has continued to support the National Electric Vehicle Infrastructure Working Council's (IWC) efforts to develop a standard electric vehicle infrastructure. This support has been in both the form of matching EPRI's funding of IWC activities and in providing technical experts to several of the IWC committees. In addition to the Steering Committee, the five areas of work and committees are:

- Charging Controls and Communications
- Connector and Connecting Stations
- Load Management, Distribution and Power Quality
- Personnel Protection
- Bus and Non-Road Vehicles.

**International Energy Administration.** DOE is also participating in two International Energy Administration (IEA) activities via the Field Operations Program. One of the two IEA activities is Annex IV, which is working on worldwide electric vehicle infrastructure issues such as emerging technologies and coordinating infrastructure development across national boundaries. Some of the specific issues that Annex IV is working on include:

- Infrastructure development
- Cost of infrastructure
- Infrastructure standards
- Effect of EVs on local power distribution networks
- Performance evaluation of charging systems.

The second IEA activity is the Annex VIII project which addresses the Market Introduction of Hybrid and Electric Vehicles. This program is attempting to incorporate a structured exchange of experience as to the many hybrid and electric vehicle fleet tests and market introduction programs and regulations that have been sponsored by different governments. IEA anticipates that a structured exchange of experiences can help build on positive electric vehicle operations and infrastructure experiences and help to eliminate replicating other countries' pitfalls.

**Presentations.** The Field Operations Program continues to participate in both national and international conferences as venues to disseminate the Program's testing results and activities. Participation has included presenting papers and as exhibitors. These conferences include:

- North American Electric Vehicle Infrastructure (NAEVI) conference
- National Clean Cities conference
- Electric Vehicle Symposia
- International Symposium on Automotive Technology & Automation (ISATA)

Program personnel often comply with requests to present testing results as well as overall Program activities to group meetings such as Electric Vehicle Association of America electric vehicle workshops, state and local alternative fuel groups, and regional Clean Cities meetings.

## **12. FUTURE ACTIVITIES**

The Field Operations Program will continue to act as an independent source of vehicle testing in order to provide the potential vehicle purchaser or leasor with accurate, unbiased vehicle performance information. By providing unbiased information, the Field Operations Program can help fleet managers significantly lower their risk when procuring alternatively fueled vehicles. Probable candidates for future testing and data acquisition include hybrids, advanced electric vehicles (i.e., designed as such rather than conversions), vehicles with advanced key components (e.g., energy storage devices, system control, driveline, and devices resulting from PNGV findings), and other alternative-fueled vehicles.

Incremental funding activities will likely continue in future fiscal years if sufficient funding is provided. In addition, there have been requests from federal agencies to expand the National Loaner Program to additional cities; again, this is dependent on future funding. Technical support to other federal agencies will also continue, as will efforts to disseminate test results.